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Applied Mechanics Reviews

A Critical Review of the World Literature in Applied Mechanics

L. H. DONNELL, *Editor*

T. VON KÁRMÁN, S. TIMOSHENKO, *Editorial Advisers*

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Abbreviations of units follow the standard of Abbreviations for Scientific and Engineering Terms of the Am. Standards Assoc. Examples: psi (pounds per square inch); cps (cycles per second); mph (miles per hour).

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Applied Mechanics Reviews

A Critical Review of the World Literature in Applied Mechanics

October 1948 Vol. 1, No. 10

General Kinematics, Statics, Dynamics

1441. **K. H. Grossmann, "Elementary derivation and refinement of Hurwitz's stability criterion (Elementare Begründung und Verschärfung des Hurwitzschen Stabilitätskriteriums)," *Schweiz. Arch.*, Aug. 1948, vol. 14, pp. 242–247.**

The Hurwitz criterion concerns the stability of systems represented by a set of linear homogeneous differential equations with constant coefficients. For solutions of the type $V_k e^{zt}$ of such a set the characteristic determinant is a polynomial function $w = f_n(z)$ of degree n, with complex z.

If the zeros of $f_n(z)$ have negative real parts in the z-plane, the system is stable; the "measure" of stability δ is determined by the line $x = -\delta$ lying furthest from the imaginary axis and having these zeros to its left. Four versions of this stability criterion are deduced by mapping $x = -\delta$ into the w-plane and performing certain algebraic transformations. The last and most elegant version reduces to $\Delta_s > 0$, $s = 1 \ldots n$, where Δ_s is a Hurwitz determinant derived from $f_n(z)$. References are made to the work of Leonhard-Bader and Routh. G. A. Nothmann, USA

1442. **E. A. Barbashin, "On dynamical systems with a velocity potential" (in Russian), *Notes Acad. Sci. USSR* (*Doklady Akad. Nauk SSSR*), July 11, 1948, vol. 61, pp. 185–187.**

A dynamical system S (of equations $\dot{x}_i = X_i$) is linear if a coordinate transformation converts all its motions into uniform motions. The author shows that if the inequality $\Sigma X_i(\partial u/\partial x_i) \geq k > 0$ has a solution, the system is linear.

A state S_0 of a system S is a "wandering" state if the system starting from the state S_0 will eventually stay a finite distance away from S_0. The paper shows that if $\Sigma X_i dx_i$ is an exact differential, each state of S is either wandering or one of equilibrium. A. W. Wundheiler, USA

Gyroscopics, Governors, Servos

(See Rev. 1441)

Vibrations, Balancing

(See also Revs. 1452, 1550, 1554)

1443. **A. Kleiner, "Angular amplitude and speed fluctuations in reciprocating engines" (in English), *Sulzer tech. Rev.*, 1947, no. 3/4, pp. 23–32.**

It is shown that some of the widely used specifications regarding permissible angular amplitude and degree of irregularity (percentage of speed fluctuations) are an obstacle to the rational design of reciprocating engines for alternating-current sets. The degree of irregularity and the angular amplitude of reciprocating engines are commonly calculated with the assumption of a torsionally rigid shaft, and this method leads to values which are usually too low. On the other hand, it is shown that the values set by the specifications are unnecessarily cautious for modern high-speed multicylinder engines.

The article describes the method used by Sulzer Brothers for the determination of the degree of irregularity of Diesel-electric sets. This method considers the exact system of forced torsional vibrations. The data that are required to carry out such an analysis are generally available in advance, since the investigation of torsional vibrations of the shaft is a necessity in all modern reciprocating engines. Joseph V. Foa, USA

1444. **O. Föppl, "Matching of angular speeds of rotating shafts. Theory (Zuordnung von Drehzahlen unlaufender Rotoren. Theoretischer Teil)," *Schweiz. Bauztg.*, Jan. 17, 1948, vol. 66, pp. 31–33.**

In this paper the interaction of two rotating machines with two different numbers of revolutions n_1 and n_2 is studied. The author draws attention to the fact that conjugated pairs of values n_1 and n_2 exist, for which one of the two machines affects perceptibly the behavior of the other. C. B. Biezeno, Holland

1445. **A. Romanowski, "Matching of angular speeds of rotating shafts. Experiments (Zuordnung von Drehzahlen unlaufender Rotoren. Experimentelle Untersuchungen)," *Schweiz. Bauztg.*, Jan. 24, 1948, vol. 66, pp. 52–54.**

A full description is given of the apparatus used by the author to verify the theoretical results which are obtained on the same subject by O. Föppl [*Schweiz. Bauztg.*, Jan. 17, 1948, vol. 66, p. 31]. Satisfactory agreement between theory and experiment is shown to exist. C. B. Biezeno, Holland

1446. **J. A. Fay, "A method of determining the natural frequencies of bending vibration of uniform beams," *J. Amer. Soc. nav. Engrs.*, Aug. 1948, vol. 60, pp. 316–331.**

A method of calculation is presented which is similar to that of N. O. Myklestad, who assumed the mass to be concentrated at a finite number of points between beam segments. The present method innovates by assuming the mass of the beam to be uniformly distributed along each segment. A numerical example is given for one assumed frequency of a marine propeller shaft having four supports. Stanley U. Benscoter, USA

📖1447. **Per Draminsky, "Damping in crankshaft vibrations (Daempningen ved torsionssvingninger i krumtapaksler)," Nyt nordisk forlag Arnold Busck, Copenhagen, 1947. Paper, 6.75 × 10 in., 166 pp., 38 figs.**

In this book the author gives an extension of the theory of Shannon, that the damping is mainly due to small transverse movements of the shaft in the bearings. It is shown that this theory is in accord with hydrodynamical theory for cylindrical bearings. Experiments were carried out with Diesel engines and shafts to confirm the theory, and the transverse movements in

the bearings were measured and photographed with an oscillograph, thus removing any doubt about their nature.

In order to isolate the main-bearing damping, the shaft was run without connecting rods, being driven by an electric motor, with vibration impulses supplied from outside by a special pulsator. As a by-product of the experiments it was shown that very short bearings have a greater load capacity than indicated by the common hydrodynamical theory, because the oil temperature is low due to the increased oil flow through such bearings.

For a shaft of mild steel the hysteresis damping factor was found to be absolutely constant for torsional stresses up to the fatigue limit, after which the damping rose sharply. It would seem that hysteresis measurements would be helpful for determining exact fatigue limits.

The author shows that the apparent damping in engine crankshaft systems is not as great as was supposed by Ker Wilson. Some attention is given to external damping in connected machines especially hydraulic couplings, for which a well-composed theory using vector diagrams is given.

This book indicates considerable progress in methods for the solution of torsional vibration problems.

A. R. Holm, Denmark

1448. J. von Freudenreich, "The chattering of safety valves and similar mechanisms" (in English), *Brown Boveri Rev.*, May-June 1948, vol. 35, pp. 147–150.

The equations of motion of a spring-loaded safety valve are formulated. These equations indicate only stable (that is, damped) oscillations when the valve is acted on by an incompressible fluid, but have unstable solutions if the fluid is compressible.

An example of a valve in an air-oil line is given, and instability is found for a certain range of air-oil mixtures. It appears that to get out of this range would necessitate abnormally low or high proportions of air in the oil; moreover, the amount of mechanical damping generally present is far from sufficient. Accordingly, chattering can be prevented only by employing special constructions to insure an adequate amount of damping.

John W. Miles, USA

1449. T. Manacorda, "Forced vibrations of a particular nonlinear vibrating system (Vibrazioni forzate di un particolare sistema oscillante non lineare)," *R. C. Accad. Lincei*, May 1948, ser. 8, vol. 4, sem. 1, pp. 557–561.

The author considers the analytical solution of the following nonlinear problem. An elastic string is stretched between two fixed points A and B. A point-mass m is fastened to the center of the string, and is set vibrating through a finite transverse amplitude by a periodic force $mf(t)$, where $f(t)$ is assumed to be antisymmetrical so that $f(-t) = -f(t)$.

The transverse displacement of m as a function of time is defined by an integral equation. From this equation an upper limit to the amplitude of motion is obtained by a procedure of successive approximation, and it is shown that one and only one periodic solution for the displacement is possible for all, except certain special values of the mechanical constants of the system.

Walter Ramberg, USA

Wave Motion, Impact

(See also Revs. 1475, 1491)

1450. M. P. White and LeVan Griffis, "The propagation of plasticity in uniaxial compression," *J. appl. Mech.*, Sept. 1948, vol. 15, pp. 256–260.

The paper consists of a rather condensed but independent version of several of the authors' OSRD reports concerning an idealized projectile striking a target hammer. As the impact velocity increases, various modes of behavior succeed each other, as summarized in the authors' words as follows: "A theoretical study of the mechanism of uniaxial compression impact and plastic wave propagation indicates that a number of different kinds of behavior are possible, depending upon the impact velocity. These are as follows: (1) Elastic impact; impact stress is proportional to impact velocity. (2) Normal plastic impact; this corresponds to the behavior in tension impact, which has been extensively studied. The impact stress is less than that which would occur in elastic impact at the same velocity. (3) Normal shock-wave behavior; stress and strain propagate as a shock wave with very large stress-strain gradients, corresponding generally to the shock waves found in gases. (4) Flowing deformation; the impact is too severe for the material to retain coherency, and therefore it flows continuously toward and along the surface of the target or hammer. (5) Supersonic impact; the impact velocity exceeds the speed of an elastic wave in the medium, and the impact phenomena depend mostly upon the density of the medium and the striking velocity. In this case, the impact stress is proportional to the square of the striking velocity."

No experimental results or applications are discussed, although a hypothetical example dealing with copper is given.

George Halsey, USA

1451. E. Hardtwig, "On the theory of Rayleigh waves with given initial conditions (Über die Anfangswertaufgabe in der Theorie der Rayleighwellen)," *Z. angew. Math. Mech.*, Apr. 1947, vol. 25/27, pp. 1–13.

The differential equations of motion of a "nearly elastic" medium (that is, one in which the stress tensor contains viscous terms linear in the velocity, as well as elastic terms linear in the displacement) are applied to a body filling a half space, bounded by a plane. The condition for the existence of Rayleigh waves is found to be that the viscous constants are porportional to the elastic ones, and in the ensuing work the usual assumption for the earth's crust, the equality of the Lamé constants λ, μ, is made.

Solutions are obtained in two and three dimensions (in the latter case in cylindrical co-ordinates) for the surface displacements due to an initial surface distribution of normal displacement and velocity. The integrals are simplified by the assumption that the viscous constants are very small, and in the case of the elastic medium well-known formulas of wave theory are recovered.

W. G. Bickley, England

Elasticity Theory

1452. Gr. C. Moisil, "On a generalization of the Airy function (Sur une generalisation de la fonction d'Airy)," *Bull. Éc. polyt. Jassy*, Jan.-June 1948, vol. 3, pp. 156–163.

The author extends the Airy-stress function of static plane elasticity to include two types of problems with acceleration, one concerning the plane motion of an incompressible viscous fluid, the other concerning plane elastic vibrations. In the first case the differential equation $(\rho\partial/\partial t - \mu\Delta)\,\Delta(\partial^2/\partial x\partial y)\theta = 0$ is given for each of two functions (represented by θ) which permits satisfaction of the condition of incompressibility, the equations of motion with a $\rho\partial u/\partial t$ term and stress-velocity relations of the form $\sigma_x = p - 2\mu\partial u/\partial x$. In the second case the differential equation $[\rho\partial^2/\partial t^2 - (\lambda + 2\mu)\Delta]\;[\rho\partial^2/\partial t^2 - \mu\Delta]\;\varphi = 0$ is given for each of three functions (represented by ϕ) which permits satisfaction of the equations of motion with a $\rho\partial^2 u/\partial t^2$ term and Hooke's law

in terms of displacements. In each case one of the functions gives Airy stress components.

No solutions or methods for solution of any problem are mentioned, but once one of the functions of the set is found, the remaining function can apparently be determined by straightforward integration. There are several important typographical errors which are quite confusing. D. C. Drucker, USA

1453. **M. Caquot, "The effect of a normal force, uniformly distributed along a straight line, on a semi-infinite body" (Action sur un massif, limité à un plan, d'un charge distribuée sur une droite de ce plan, normalement à celui-ci et de densité constante ρ par unité de longueur),"** *Ann. Ponts Chauss.*, Jan.-Feb. 1948, vol. 118, pp. 83–86.

The author shows a simple solution of this problem which has previously been solved by Flamant with the use of Boussinesq's solution. Enrico Volterra, Italy

1454. **B. E. Gatewood, "Note on the thermal stresses in a long circular cylinder of $m + 1$ concentric materials,"** *Quart. appl Math.*, Apr. 1948, vol. 6, pp. 84–86.

This note extends the author's previous work on thermal stresses in a long cylinder to $(m + 1)$ concentric layers of different materials. The normal stresses and displacements expressed in terms of the function V defined by $\nabla^2 V = kT$ and the biharmonic function $U(\nabla^2 U = 0)$, where T represents the temperature and k is a constant of the given material, are taken to be continuous at the junction surfaces and zero on the outside surface. U is expressed in terms of two analytic functions $\varphi(z)$ and $H(z)$ which in turn are expressed by Laurent and power series.

The boundary conditions, when integrated over the circle by Cauchy's formula, lead to a set of equations which determine the coefficients of the series. In the particular case when the temperature is a function of the radius only, the series reduce to one term only, and the results become very simple; they are given by the author. R. N. Ghosh, India

Experimental Stress Analysis

1455. **G. Brewer, "The equilateral fleximeter,"** *Proc. Soc. exp. Stress Anal.*, 1948, vol. 6, no. 1, pp. 123–130.

A new fleximeter is described which utilizes unbonded wire-gage elements to record the bending strains in three directions simultaneously on a small area of the surface of a plate structure such as a storage tank or ship hull. This information, together with strain data obtained on the accessible side of the structure by the use of a conventional strain-gage rosette, permits calculation of the state of stress at the inaccessible surface. Charles W. Gadd, USA

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 1444, 1445, 1454, 1461)

1456. **J. Hintloglou, "Design of steel beams under bending load taking into account the deformation reserve due to plastic flow (Bemessung auf Biegung beanspruchter Stahlbalken unter Berücksichtigung der Formänderungs-reserve im plastischen Spannungszustand),"** *Bauplan. Bautech.*, May 1948, vol. 2, pp. 159–164.

"In the following investigation we consider the safety of a structure exhausted only if at a certain point the stresses begin to increase beyond all limits although the loads are left unchanged." On the basis of this definition an apparently new theory of the strength of steel girders and beams is developed, which, as the examples computed indicate, leads to 10 to 15 per cent weight saving compared with a structure computed in the conventional fashion. The connection of the new method with established theory of plastic flow is, however, not worked out, so that it would be difficult to judge the reliability of this ad hoc plasticity theory of steel girders. Paul Neményi, USA

1457. **J. A. Haringx, "Conical disk springs"** (in English), *Philips tech. Rev.*, 1948, vol. 10, no. 2, pp. 61–66.

The author discusses the load-compression characteristics and the resulting advantages and limitations of conical disk springs. A design problem is included. Albert I. Bellin, USA

Plates, Disks, Shells, Membranes

(See also Revs. 1459, 1460, 1462, 1463)

1458. **F. A. Bakhshiyan, "Finite deformations of a hollow sphere subjected to internal pressure"** (in Russian), *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*), Mar.-Apr. 1948, vol. 12, pp. 137–140.

The author solves the problem indicated in the title, assuming a uniform internal pressure and isotropic material. He starts with the equation of equilibrium of an element

$$(r + u)^2 d\sigma_r + 2(r + u)(dr + du)(\sigma_r - \sigma_\varphi) = 0$$

where u is the displacement in the direction of the radius r, and σ_r is the stress in the radial and σ_φ in the perpendicular direction.

Introducing $r + u = v$ as a new variable, and putting $\sigma_s = \sigma_\varphi - \sigma_r$, the author determines the general integral in the form

$$(2\sigma_s/3k)r^3 + C_1 = \int (v^2 dv)/(C + \log v)$$

where C and C_1 are integration constants, and k is a parameter of the equation $\sigma_r = k\theta - (2/3)\sigma_s$, where $\theta = (v^2/r^2)dv/dr - 1$.

On the basis of this solution the author examines several individual cases, in which the deformation is completely elastic or completely plastic. He obtains exact or approximate formulas which are applicable to practical problems.

M. T. Huber, Poland

Buckling Problems

1459. **F. Werren and C. B. Norris, "Effect of axial stiffeners on the buckling properties of thin curved plywood plates in axial compression,"** *For. Prod. Lab. Rep.*, no. 1567, Mar. 1948, pp. 1–14.

This paper presents test data on curved plywood plates tested in axial compression. Each plate was made in the shape of a cylindrical arc and had a single axial stiffener at the center. A few plates were tested without stiffeners. The test results show that the stiffener does not increase the buckling stress of the plywood. However the stiffener carries additional load and if stiff enough breaks up the pattern of buckling. The buckling stress of the curved plates tested is approximately equal to that of a thin-walled plywood cylinder and may be calculated as such.

Evan A. Davis, USA

1460. **C. F. Kollbrunner and G. Herrmann, "Theoretical studies on buckling by the T. K. V. S. B. in 1947 (Theoretische Beuluntersuchungen der T. K. V. S. B. im Jahre 1947),"** *Schweiz. Bauztg.*, Mar. 13, 1948, vol. 66, pp. 146–149.

Theoretical values are given for the buckling loads of flat rec-

tangular plates with the top and bottom edges simply supported (the plate being in the vertical plane) under a vertical compressive stress varying linearly across the width from zero at one side. The conditions on the two vertical edges are (1) both simply supported, (2) both clamped, (3) one clamped, one simply supported, (4) one clamped, one free, (5) one simply supported, one free. Curves for the buckling load are given for cases (4) and (5) for various panel side ratios. For the other cases values are tabulated for the length of plate which has the least buckling load for a given width.

The Rayleigh-Ritz method is used, the assumed deflection being a double series of terms $a_{mn}X_mY_n$, X_m being sinusoidal, and Y_n the deflection in a normal mode of a bar. First, second, and third approximations are worked out, using one, two, and three terms of the series. The paper is a brief account of a longer report to be published shortly.

The reviewer observes that a deflection function Y_n satisfying the conditions at the free end of a bar does not satisfy the corresponding conditions of a plate, and that the results may be in error on this account. J. N. Goodier, USA

1461. Witold Wierzbicki, "Nonelastic buckling of statically determinate supported rods," (in Polish), *Inżyn Budown*, Nov. 1947, vol. 4, pp. 435–437.

The paper offers a generalization of known empirical results, concerning nonelastic buckling of a straight bar, to cases that have not been experimentally investigated.

Von Kármán's 1910 paper serves as a starting point. In his equation $EJy'' = -M$, the elastic modulus E is replaced by a reduced modulus N, depending on the physical properties and the cross section and shape of the beam. This equation applies to the case of axial loads distributed along the axis of the bar and the critical load is derived for such cases as $P_k = (\pi^2NJ)/(\mu l)^2$ or $P_k = (\pi^2N'J)/l^2$ where μ depends on the distribution of the loading and $N' = N/\mu^2$.

The author compares the critical stresses derived from the last equation with those obtained for hinged ends in Tetmajer's tests, and obtains a relation between the modulus N and the slenderness ratio of the beam. A graph of this relationship is shown for steel wire. The paper concludes with examples of the determination of the critical load for nonelastic buckling under various types of loading. W. Olszak, Poland

1462. S. B. Batdorf and M. Schildcrout, "Critical axial compressive stress of a curved rectangular panel with a central chordwise stiffner," *Nat. adv. Comm. Aero. tech. Note*, no. 1661, July 1948, pp. 1–23.

The problem stated in the title is discussed theoretically under the assumption that the stiffener is located at the middle surface of the curved panel, and has only bending stiffness to restrain the radial deformation of the shell. The general equation of equilibrium of a cylindrical shell [S. B. Batdorf, *Nat. adv. Comm. Aero. tech Note*, nos. 1341 and 1342, June 1947] is modified by the addition of a Dirac delta function multiplied by a suitable factor to represent the effect of the stiffener. The resulting partial differential equation is solved by the Galerkin method.

It is found that the stiffener tends to increase the critical axial stress. The increase, however, is very small and is zero when the ratio of the circumferential dimension to the axial dimension of the panel is less than 0.7. Tables and curves are given from which a coefficient for computing the theoretical stress can be determined. Since a panel of moderate or large curvature buckles in compression at a stress considerably below the theoretical value, a method is suggested for estimating the design critical stresses. G. H. Handelman, USA

1463. S. Levy, R. M. Woolley, and W. D. Kroll, "Instability of simply supported square plate with reinforced circular hole in edge compression," *J. Res. nat. Bur. Stands.*, Dec. 1947, vol. 39, pp. 571–577.

A method is presented for computing the compressive buckling load of a simply supported elastic rectangular plate having a central circular hole reinforced by a circular doubler plate. The stress distribution just prior to buckling is obtained by the method of G. Gurney [*Rep. Memo. aero. Res. Counc. Lond.*, no. 1834, Feb. 1938]. The buckling stress is then computed by the energy method, using Gauss's method of numerical integration.

Numerical values are obtained for the buckling stresses of six square plates with central holes of various sizes, some of which are reinforced. It is found that the buckling stresses are only slightly reduced by the presence of unreinforced holes, a 14 per cent reduction occurring for a hole diameter equal to half the width of the plate. Reinforcement of a hole by a doubler plate is found to cause a substantial increase in buckling load. The increase in buckling load appears to be dependent primarily upon the volume rather than the shape of the doubler plate.

S. B. Batdorf, USA

Joints and Joining Methods

(See also Rev. 1465)

1464. T. D. Tuft, "Tensile tests of small-scale welded joints," *David Taylor Model Basin Rep.*, no. R-347, Mar. 1948, pp. 1–20.

Small-scale welded specimens embodying four common types of joints were fabricated from black iron sheet, and tested in tension to determine the relative effectiveness of Everdur brazing as compared with steel welding for joining thin metal sections. Everdur welds were not as strong or as ductile as those of steel, but Everdur butt welds withstood stresses in the neighborhood of 30,000 psi.

Results obtained by varying the width of tensile specimens indicated that the behavior of a standard tensile specimen provides only a limited guide to the behavior of metal in an actual structure. T. J. Dolan, USA

Structures

(See also Revs. 1463, 1473)

1465. R. A. Hechtman and B. G. Johnston, "Riveted semirigid beam to column building connections." *Amer. Inst. Constr. Rep.*, no. 206, Nov. 1947, pp. 1–117.

This booklet is a report on (1) an experimental investigation of the restraining moment of beam to column connections, and (2) an evaluation of the test results for use in the calculation of beams with full advantage taken of end moments induced by the connections. Each of 47 test assemblies consisted of a symmetric arrangement of a column stub, with equal portions of beams on either side of it, loaded symmetrically so as to exclude rotation of the column stub.

The plot of the restraining end moment of the connection versus the angle of rotation of the beam end relative to the column stub, together with theoretical considerations, provide data for a proposed standardization comprising 5 types of top and seat angle connections to column. For these, dependable restraint values are given to be used with wide flange beams ranging in size from 12 in. to 21 in., beam spans from 10 ft. to 34 ft. These are based on a maximum bending stress of 33,000 psi at 1.65 times normal load, reduced where necessary in order that the maximum stress in the tension rivets does not exceed 1.65 times 15,000 psi, also at 1.65 times normal load. All of this applies when there is no rotation of the column at its connection to the beams.

Next investigated is the case where rotation of the column does take place, as for example when the beam is a member of a frame. For the calculation of such beams the authors present graphs for uniformly distributed center, third, and fourth point loading of the beam. Three illustrative examples are given of the use of these graphs, showing the saving in weight and the reduction in the depth of beam that can be achieved if the restraining effect of the connections is considered. Two appendixes are included, namely: (A) which deals with nonsymmetric loading of the horizontal member of a single bent; and (B) which gives detail sketches of 19 of the test assemblies, logs of the tests, their M, φ diagrams, and photos at failure. F. Hymans, USA

Rheology (Plastic, Visco-Plastic Flow)

(See also Revs. 1447, 1450, 1451, 1456, 1471, 1473)

1466. **W. Prager, "The stress-strain laws of the mathematical theory of plasticity—a survey of recent progress,"** *J. appl. Mech.*, Sept. 1948, vol. 15, pp. 226–233.

The author of this paper has rendered a much needed service in surveying the progress made in applying the various stress-strain laws of the mathematical theory of plasticity. The stress-strain laws are simplified as much as possible without losing their essential features and the discussion is restricted to small displacements and strains. The plastic material considered in the discussion is assumed to be isotropic, inviscid, and incompressible.

The author contrasts the "physical" theory of plasticity with that of the "mathematical" theory and points out that the mathematical theory discusses the plastic behavior of a material on a purely phenomenological basis.

The author discusses and compares laws of both flow and deformation types with reference to the conditions of continuity and uniqueness necessary to give them a physical meaning. A clear explanation of the basic concepts is presented, making it easy to follow the discussion throughout the paper. The various laws and the conditions under which they yield identical results are examined. The manner in which the laws may be generalized is shown and methods of integration are given. A bibliography is included. C. O. Dohrenwend, USA

1467. **S. J. Fraenkel, "Experimental studies of biaxially stressed mild steel in the plastic range,"** *J. appl. Mech.*, Sept. 1948, vol. 15, pp. 193–200.

Tubular test specimens of medium steel were subjected to essentially static simultaneous axial tension and internal pressure at room temperature, so that controlled conditions of biaxial stresses could be obtained. The purposes of these tests are outlined as follows: (1) to obtain a check on the "third rule of plastic flow," which states that Mohr's stress and strain circles are geometrically similar for all stress ratios; (2) to study the absorption of energy up to fracture and up to some arbitrarily chosen strain magnitude as a function of biaxial stress ratio; and (3) to determine the effect of the path of loading in arriving at a given stress condition.

The author concludes: (1) The third rule of plastic flow does not generally apply to medium steel, although a quantitative determination of the deviation cannot be made until more precise strain measurements are made. (2) The amount of energy absorbed per unit volume, for a given maximum strain, is quadratic in the stress ratio n. A tentative empirical relation is given as $W = W_t(1 + n^2)$, where W is the strain energy per unit volume, and W_t refers to the strain energy per unit volume for simple tension. Because of experimental difficulties no quantitative conclusions were made concerning energy to rupture although some experimental curves are presented. (3) It was concluded that the octahedral shear stress associated with a certain set of orthogonal strains is independent of the order in which these strains are applied to the metal, provided that this is done so that the metal at no time has any residual reversed strains; subject to this condition, the principle of superposition was therefore demonstrated as applying in the plastic range for the experiments performed. Irwin Vigness, USA

1468. **K. N. Shevchenko, "The elasto-plastic state under a concentrated load applied to a half plane"** (in Russian), *Notes Acad. Sci. USSR* (*Doklady Akad. Nauk SSSR*), July 1, 1948, vol. 61, pp. 29–30.

The paper is concerned with the stresses and strains set up in the elasto-plastic half plane $x>0$ by a concentrated force which is applied at the origin and acts along the positive x-axis. The author assumes that the well-known elastic stress distribution remains valid even when part of the material has become plastic. Using Hencky's stress-strain relations for a strain-hardening material, he then proceeds to show that the plastic strains obtained on the basis of this assumption satisfy the equation of compatibility. (No attempt is made, however, to verify whether the displacements possess the necessary continuity across the boundary between the elastic and plastic regions.) W. Prager, USA

Failure, Mechanics of Solid State

1469. **E. A. Davis, "The effect of size and stored energy on the fracture of tubular specimens,"** *J. appl. Mech.*, Sept. 1948, vol. 15, pp. 216–221.

Internal pressure tests on tubular specimens are described in this paper. Tests were run on three sizes of specimens. In one half of the tests, a high-pressure chamber was used in connection with the specimens to store additional energy in the test system. Both pure internal pressure and pure circumferential tension tests were made.

The size effect as shown by the tests was negligible. The effect of the stored energy appeared only after the fracture actually started. In the high-energy tests the extent of the fracture was much greater than in the low-energy tests. Frederick Seitz, USA

Design Factors, Meaning of Material Tests

(See also Rev. 1476)

1470. **W. G. Stoeckicht, "Importance of design factors for marine reduction gears,"** *J. Amer. Soc. nav. Engrs.*, Aug. 1948, vol. 60, pp. 332–339.

A general discussion of criteria for the design of reduction gears is presented in this paper. Maximum contact stress, endurance limit, hardness of steel used, bending strength of gear teeth, and minimum wear are briefly discussed. The author advocates design on the basis of the endurance life for contact stresses. He emphasizes that calculated life expectancy due to bending should be much greater than that due to contact stress. B. Bresler, USA

1471. **C. J. Geyer, Jr., C. H. Reichardt, and George Halsey, "A theory of commercial yarn testing,"** *J. appl. Phys.*, May 1948, vol. 19, pp. 464–472.

The paper analyzes the usefulness of a three-element model, consisting of a spring and a Maxwell unit of nonlinear viscosity

coupled in parallel, in deriving the viscous constants of yarns and fibers from constant rate of elongation and constant rate of loading tests. The Maxwell unit consists of another spring in series with a dashpot which is defined by the hyperbolic sine law developed by Eyring from the concept of the rate process. The mathematical theory of the model is developed for both types of tests.

The authors describe experiments on viscose-rayon tire cord yarn and single filaments in which several load cycles of increasing amplitudes were imposed, and the inelastic behavior was observed. From the test results the deformational characteristics of the yarns were computed with the aid of the relations developed for the three-element model.

A. M. Freudenthal, USA

Material Test Techniques

(See also Revs. 1447, 1471, 1556)

1472. F. L. Roth and R. D. Stiehler, "Strain test for evaluation of rubber compounds," *J. Res. nat. Bur. Stands.*, Aug. 1948, vol. 41, pp. 87–93.

The authors claim that measurements of the elongation of rubber vulcanizates at a fixed stress may be made with such precision that variations arising during preparation of the material may be studied in much greater detail than when the stress to cause a predetermined elongation is measured.

Variations in strain obtained during tests on pieces cut from the same sheet are discussed, the effects of aging are studied, and the paper concludes with a reference to the effect of time of curing on elongation. These data may be expressed in terms of three parameters, to which the authors refer as a "scorch time," K a reaction rate constant, and E_∞ the "structure factor" which corresponds to the elongation for infinite cure time. The relationship has been shown to apply to vulcanized GR-S and GR-M and to natural rubber provided the stress is insufficient to cause crystallization.

F. T. Barwell, England

1473. M. G. Dawance, "A new method for the study of relaxation in steel wires (Une nouvelle méthode pour l'étude de la relaxation des fils d'acier)," *Batim. Trav. publics*, Feb. 1948, no. 9, pp. 1–8.

The author describes a new method, applied by the Institut Technique du Bâtiment et des Travaux Publics, Paris, for studying relaxation (creep under constant elongation) in steel wires used for prestressed concrete constructions.

The steel wires are stressed on strong steel frames and anchored at their ends. The stresses in them are determined from time to time by means of an electroacoustical method which measures the free vibration frequencies of the wires with the use of Coyne's "Témoin sonore" [*Batim. Trav. publics*, ser. I, no. 16]. The influence of the flexural rigidity of the wires on their free vibration frequencies is taken into consideration.

The stress is determined to an accuracy of one per cent. The method is very simple and requires little test material so that no special precautions are required for conserving it.

The results of some relaxation tests on steel wires with diameters varying from two to five millimeters are reported and discussed.

Giulio Ceradini, Italy

1474. W. L. Holt, E. O. Knox, and F. L. Roth, "Strain tester for rubber," *J. Res. nat. Bur. Stands.*, Aug. 1948, vol. 41, pp. 95–102.

The paper describes a simple method for measuring the percentage elongation of rubber specimens under a predetermined tensile load acting for a predetermined time.

Methods of preparation of test pieces, apparatus, and method of operation are discussed in considerable detail, and it is apparent from the particulars given that the authors have taken considerable trouble to ensure accuracy and reproducibility of results by this method. They claim that greater accuracy may be attained by measuring the strain resulting from a given stress than by measuring the stress resulting from a given strain.

F. T. Barwell, England

1475. D. S. Clark and P. E. Duwez, "Discussion of the forces acting in tension impact tests of materials," *J. appl. Mech.*, Sept. 1948, vol. 15, pp. 243–247.

The principles of analysis developed by Bohnenblust, Charyk, and Hyers are applied to the determination of force-time relationships in axially loaded specimens of infinite and finite length. An impact machine utilizing a resistance gage, mounted on a standard bar, as the force-indicating element is described. Results of an impact test at 150 fps on a 0.300-in. × 8-in. specimen of 1020 cold-rolled steel are compared with theoretical stress-time diagrams for the specimen. The ultimate impact strength as measured is somewhat higher than the computed one, and about equal to the static ultimate.

Glenn Murphy, USA

1476. P. Dubois and A. Dumez, "Contribution to the study of hardness (Contribution a l'étude du problême de la dureté)," *Mémo. Soc. Ing. civ. Fr.*, May-June 1947, vol. 100, pp. 343–371.

The authors define the hardness of a material as its resistance to penetration. In Part I they give a critical review of existing methods of measurement (static, dynamic, kinematic), pointing out the lack of consistency and scientific approach which they involve. The various scales of hardness do not necessarily indicate identical relative hardness for the same two materials. Thus by one method, copper is harder than steel while another indicates the opposite.

In Part II the authors describe their research on the kinematic measurement of hardness, in which they investigate: (1) Definition of the conditions of penetration and the use of an apparatus which registers curves of force F as a function of penetration P; (2) the role of the nature and form of the penetrator; (3) separation of the influence of elasticity, plasticity, friction, etc., on the results.

For conical and pyramidal penetrators the curves closely agreed with an $F = KP^2$ relationship where K is a constant depending for a given material on the shape of the penetrator and some time factors. For precisely defined conditions K can be regarded as the measure of hardness. Curves were also drawn showing the work per unit volume displaced for various cone angles. For a ball penetrator the F versus P relation is not parabolic, because of the change in the shape of the indentation as penetration progresses.

The results show that the relative hardness of two materials change if the shape of the penetrator or other conditions are altered. The authors conclude that hardness should not be given as a single quantity but rather as the combination of several quantities, dependent on the conditions under which the measurement is carried out. The plasticity and elasticity of the material to be tested determines the most suitable methods and scales to be used.

Nicholas Sag, Australia

Mechanical Properties of Specific Materials

(See also Revs. 1471, 1472, 1474, 1475)

1477. **R. Vallette, "Granulometric composition of concrete (Composition granulométrique des bétons)"** (with summaries in English and German), *Publ. int. Ass. Bridge Struct. Engng.*, Prelim. Publ. 3rd Congr., 1948, pp. 163–172.

The author claims to have the final answer to the question of the practical determination of concrete compositions. The least possible amount of sand should be used in order to be able to use the least amount of water. The author argues against continuous grading as giving bad compactness. The grading should be discontinuous, composed of categories of grains of the same size, and rules are given to determine the relative size of each category to insure a better concrete with improved maximum strength and watertightness, and minimum porosity. The author describes the good results obtained by following these rules by the Society of the French National Railroads. A. J. Durelli, USA

1478. **R. C. Fitzgerald, A. B. Wilder, G. V. Smith, and A. E. White, "A study of the properties of 0.5 per cent chromium—0.5 per cent molybdenum pipe steel,"** *Weld. Res. Suppl.*, Sept. 1948, vol. 13, pp. 457–469.

Graphitization of welded joints of molybdenum steel may occur when subjected to high-pressure steam. The addition of 0.5 per cent of chromium in addition to the usual amounts of molybdenum was found to inhibit the formation of graphite without causing any appreciable change in physical properties. Gerald Pickett, USA

1479. **R. Dutron, "Vibrations of concrete and reinforced concrete (Vibration du béton et du béton armé)"** (with summaries in English and German), *Publ. int. Ass. Bridge Struct. Engng.*, Prelim. Publ. 3rd Congr. 1948, pp. 173–186.

This is a report of results obtained from several vibration tests of concrete. Radius of action of the internal vibrator as a function of plasticity of the concrete and of duration of the vibration, and volumes of concrete influenced by superficial vibration as a function of plasticity and grading are studied in particular. The influence of these variables on compressive strength, density, and porosity is given in charts and diagrams. The author also gives some other qualitative results and advice regarding good practice. A. J. Durelli, USA

1480. **G. Venturello and M. Bosio, "Nickel-beryllium brasses (Ottoni al nichel-berillio),"** *Metallurgia ital.*, 1948, vol. 40, no. 2, pp. 49–53.

Brasses of composition 70 per cent Cu, 6 per cent Ni, 0 to 1.87 per cent Be and the rest Zn, with various heat treatments, were tested with respect to hardness, malleability, and corrosion as functions of time. A content of beryllium greater than one per cent was found to render the alloy susceptible to heat treatment, with possible resulting improvements in mechanical properties and corrosion resistance. Folke K. G. Odqvist, Sweden

1481. **W. C. Brueggeman and M. Mayer, Jr., "Axial fatigue tests at zero mean stress of 24S-T and 75S-T aluminum-alloy strips with a central circular hole,"** *Nat. adv. Comm. Aero. tech. Note*, no. 1611, Aug. 1948, pp. 1–23.

Completely reversed axial load fatigue tests were made on the above materials in eccentric crank fatigue machines. Guide fixtures were used to prevent buckling in the compression half of the cycle. Specimen widths $^1/_4$, $^1/_2$, 1, and 2-in., plain and with hole diameter to specimen width ratios from 0.01 to 0.95 were used.

S-N diagrams are given for all tests. A size effect is indicated in the plain specimens, the curve for $^1/_4$-in. specimens being from 5,000 to 8,000 psi above the curve for the 2-in. width. Fatigue stress concentration factors approach unity for small diameter to width ratios. They range between 1.5 and 2.0 for larger ratios in 24S-T sheet 0.032 in. thick and are somewhat lower for the 0.064-in. thickness. The factors are higher in 75S-T sheet but in both cases are appreciably less (60 to 80 per cent) than theoretical values. Henry A. Lepper, Jr., USA

Hydraulics; Cavitation; Transport

(See also Revs. 1499, 1524, 1536, 1579)

1482. **A. Lazard, "Contribution to the theoretical study of gradually varied flow in hydraulics (Contribution à l'étude théorique du mouvement graduellement varié en hydraulique),"** *Ann. Ponts Chauss.*, Mar.-Apr. 1947, vol. 117, pp. 185–219.

The shape of the backwater curves depends on the normal depth, the critical depth, and on the sign of their difference. The author uses, in addition, the "characteristic" depth at which the tangent to the backwater curve is horizontal.

He shows that there are, in general, two characteristic depths and studies the shape of the backwater curves according to the numerical order of the normal depth, the critical depth and the two characteristic depths. A. Craya, France

1483. **D. Citrini, "Rectangular channels with lateral contribution of water flow (Canali rettangolari con apporto laterale di portata),"** *Energia Elett.*, May 1948, vol. 25, pp. 155–166.

General equations of motion are developed for the flow in an open channel which receives flow from the sides at a constant rate per unit length of stream. These equations take into account the forward momentum of the flow from the sides, but assume that the gravity forces and the friction forces are closely balanced and may be neglected. The assumption is also made that inflow from the side in small streams can be approximated by the same amount of flow distributed uniformly over the total length of the stream bank.

The water surface profile for a rectangular channel of constant width is then calculated by numerical integration of the equations and the results are presented in graph form for various values of the parameter $m = (l/L)\cot(\alpha/r)$, where α is the angle between the center line of the main stream and the side stream, r is the ratio of the width of the side channels to the distance between them, l is the width of the main channel and L is its length.

A solution is given for a canal of rectangular cross section with inflow from the side and uniform water depth over its entire length. The author also gives a discussion of some of the pertinent properties of his general equations. Vito A. Vanoni, USA

1484. **R. H. Hensleigh, "Some recent developments in hydraulic transmissions,"** *Proc. nat. Conf. indust. Hyd.*, 3rd meet., 1947, pp. 78–85.

Some general information concerning hydrostatic and hydrokinetic transmissions is given: (1) A brief description of their actions; (2) their advantages and disadvantages; (3) design difficulties; (4) examples of these types of hydraulic transmissions, and the troubles encountered in practical problems. P. C. Chu, USA

1485. **W. W. Hagerty, "A new factor in the design of hydraulic seals,"** *Proc. nat. Conf. indust. Hyd.*, 3rd meet., 1947, pp. 122–129.

This valuable paper describes a method of sealing a rotating shaft against leakage caused by an axial pressure gradient. Within an annulus which has the inner wall rotating and the outer wall stationary three modes of motion can exist: (1) Couette motion at low speeds; (2) Taylor vortex motion at intermediate speeds; (3) turbulent motion at high speeds. Neither (1) nor (3) has properties useful for sealing purposes but (2) has. In vortex motion, studied theoretically by G. I. Taylor for an annulus of infinite length, the fluid within the annulus divides into pairs of vortex rings which surround the rotating shaft like coils of rope and have a high degree of stability. This stability resists the leakage of fluid past the vortex rings under a pressure gradient.

The author performed experiments to verify Taylor's theoretical deductions and to determine whether the results were applicable to annuli of finite length. He found that Taylor's formula, which predicts the initial speed at which fluid motion is unstable, was correct and obtained data which make it possible to compute the number of vortex pairs that will form in an annulus when the dimensions of the annulus are given. For the application to seal design he found that the best ratio of the axial and the radial dimension of the annulus depends on experimental results, but that for very high speeds this ratio appears to approach 2.73 as a limit. Karl E. Schoenherr, USA

1486. Hunter Rouse and J. S. McNown, "Cavitation and pressure distribution," *Univ. Iowa Stud. Engng. Bull.*, no. 32, 1948, pp. 1–70.

The water tunnel of the Iowa Institute of Hydraulic Research is described and the results of an exhaustive study of pressure distribution about head forms at zero angle of yaw under cavitating conditions are given in the form of graphs. Thirty-one different head forms were mounted on a one-inch-diameter cylinder held in the test section of the water tunnel, and pressure measurements were made along the profiles of the heads. The resulting pressure distributions are plotted for each head, for a range of values of the cavitation parameter. There is some analysis and discussion of the results. Stephen H. Crandall, USA

1487. J. W. Howe and C. J. Posey, "Characteristics of high-velocity jets," *Univ. Iowa Stud. Engng. Bull.*, no. 31, June 1946 (issued in 1947), pp. 315–332.

A series of experiments is described in which the object was to investigate means of increasing the effectiveness of fire monitors and appurtenant nozzles. It was supposed that intense turbulence arising from tortuous flow through monitors of standard design, added to that due to eddy formation and boundary-layer growth in the nozzle, is a major factor in the disintegration of the issuing stream. Several combinations of monitors and nozzles constructed with the purpose of minimizing the turbulence in the approaching stream were tested. Concentrations of discharge over the stream cross section and ranges of the jet were measured. The original suppositions appear to have been well borne out since the most advantageous combination showed almost double the range of a standard three-inch monitor and nozzle delivering a $1^1/_2$-in. jet at 100 and 150 psi pressure. E. H. Taylor, USA

1488. A. H. Shapiro and R. D. Smith, "Friction coefficients in the inlet length of smooth round tubes," *Nat. adv. Comm. Aero. tech. Note*, no. 1785, Nov. 1948, pp. 1–44.

The apparent friction factors for inlet lengths of smooth round tubes with bellmouth entrances were experimentally determined for tube sizes ranging from $^3/_8$ in. to 4 in. Tests were conducted with water and with air at low Mach numbers, for a range of Reynolds numbers from 39,000 to 590,000 (based on diameter). The apparent friction factor is obtained in a manner similar to the friction factor in established flow, that is to say the variation of velocity distribution from section to section in the inlet is neglected.

The boundary layer becomes turbulent at a Reynolds number of about 5×10^5 (based on distance from tube inlet), which is in good agreement with results obtained from flow along a flat plate. In the laminar boundary zone the local apparent friction factor decreases with the distance from the inlet, and then increases sharply in the change to the turbulent boundary layer.

Over a range of Reynolds numbers 40,000 to 250,000 about 80 tube diameters are required to bring the integrated apparent friction factor to within 5 per cent of the Kármán-Nikuradse value. The introduction of turbulence into the flow by means of a screen placed upstream from the bellmouth, or by roughening of the bellmouth, caused an immediate turbulent boundary layer to result. An approximate relation between the nozzle coefficient and the friction factor is given. V. L. Streeter, USA

1489. Hunter Rouse, "Fundamental aspects of cavitation," *Proc. nat. Conf. indust. Hyd.*, 3rd meet., 1947, pp. 30–37.

This paper gives a very brief description (with historical background) of the mechanism of cavitation of fluids, gaseous or liquid. Investigations at the Iowa Institute of Hydraulic Research on the pressure variations for various shapes of obstructions to smooth flow are shown, the results being plotted against functions of the Reynolds number and a "cavitation number." Model tests can, by means of these charts, indicate full scale cavitation behavior. The effect of admission of a small amount of air to water approaching an obstruction is discussed and the fact emphasized that many of the damaging results of cavitation can thereby be lessened. H. H. Anderson, Scotland

1490. E. Derron, "Sedimentation of coarse silt (Über die Sedimentation von körnigem Schlamm)," *Schweiz. Bauztg.*, Aug. 14, 1948, vol. 66, pp. 451–453.

This paper is an attempt at a theoretical analysis of the sedimentation of coarse silt. If the falling velocity of the single element is given by Stokes's well-known law, and the granulometric distribution law is a parabola of *n*th order, a relation is obtained which gives the weight of the material still in suspension as a function of time, of initial weight, depth of sedimentation tank, and some constants of the material. Some values of these constants are obtained from experimental results.

Duilio Citrini, Italy

1491. M. Breitenöder, "Backwater due to piers as a resistance problem (Der Pfeilerstau als Widerstandsproblem)," *Bauplan. Bautech.*, Mar. 1948, vol. 2, pp. 81–85.

Methods of conventional design in related fields are applied to the hydraulic problem of flow past bridge piers. Known principles of skin friction, form drag, and wave resistance are employed to determine head losses for such flows. By means of potential and stream lines, the water surface elevations are then derived by neglecting the vertical component of velocity.

Arthur T. Ippen, USA

1492. R. M. Watson, "Cavitation in centrifugal pumps—some of the less well-known factors," *Proc. nat. Conf. indust. Hyd.*, 3rd meet., 1947, pp. 50–65.

This is a useful practical paper dealing with the incidence and mechanism of cavitation. Radial, mixed, and axial-flow pumps are described, turbulence and viscosity pumps being excluded. A

brief description is given of the mechanics of cavitation, with mathematical relationships both for normal (noncavitating) pumps and hot-well-type pumps where flow is controlled by partial cavitation.

Attention is drawn to the particular impeller-vane design required for operation under cavitating conditions. The physical limitations of hot-well and process pumps are described together with reasons why process pumps are able to run satisfactorily with some measure of cavitation. There is a brief discussion of the behavior of the liquid immediately preceding the impeller, with diagrams of probable flow at other than best load.

The reviewer's experience is in agreement with the author's general contentions and, in particular, with his chart showing variations of suction specific speed with size of pump, and therefore with Reynolds number. The author had previously suggested that there is a justification for neglecting the influence of Reynolds number and relative roughness on the cavitation performance of centrifugal pumps.

The reviewer observes that a paper by Wislicenus, Watson, and Karassik ["Cavitation characteristics of centrifugal pumps," *Trans. Amer. Soc. mech. Engrs.*, Jan. 1939, vol. 61, p. 18], should be consulted.

H. H. Anderson, Scotland

1493. **R. Shuttleworth and G. L. J. Bailey, "The spreading of a liquid over a rough solid,"** *Disc. Faraday Soc.*, 1948, no. 3, pp. 16–22.

From the classical condition of an absolute minimum of the total surface energy the authors derive the expression for the apparent contact angle of a liquid surface with a rough solid. This expression, different from that for a smooth solid, was previously derived by Wenzel (1936) in a less rigorous way.

For two-dimensional roughness (a series of parallel grooves separated by ridges) the authors discuss spreading parallel and perpendicular to the grooves. In the first case, for small contact angles the liquid will flow along the groove as in a capillary; when the angle is large, and the groove deep and narrow, the liquid will nowhere touch the bottom.

For perpendicular spreading the line of contact is parallel to the grooves and moves at right angles to them. The apparent contact angle decreases monotonically, while the true angle has a periodic variation superimposed upon this same decrease, until equilibrium is reached; being metastable, the angle is not given by the Wenzel formula. The liquid can be made to recede, and then comes to equilibrium at a smaller value of the contact angle; this is a hysteresis phenomenon. Other metastable equilibriums may be enforced by some form of mechanical spreading.

The surface near a three-dimensionally rough solid must be ragged to produce the true contact angle. If the roughness is formed by isolated pits, hysteresis is unavoidable, and subsidiary (metastable) minima of surface energy will be produced.

A. W. Wundheiler, USA

1494. **P. K. Konakov, "Coefficient of resistance for smooth pipes"** (in Russian), ***Bull. Acad. Sci. USSR Ser. tech. Sci.*** (***Izv. Akad. Nauk SSSR Ser. tekh. Nauk***), **July 1948, no. 7, pp. 1029–1036.**

The author derives from theoretical considerations the following formula for the resistance coefficient ζ for a smooth pipe: $\zeta^{-1/2} = A \log R - B$, where ζ and R (the Reynolds number) are computed with the diameter rather than the hydraulic radius. Comparison with the data of Nikuradze gives values for A and B of 1.8 and -1.5 respectively. There seems to be excellent agreement with the formula for $3.5 < \log R < 6.5$. The validity of the formula is claimed only for $R < R_0 = 10^{(1.5k - 1)/1.8k}$ where K is a constant depending upon roughness characteristics of the pipe. For $R > R_0$ the author predicts that $\zeta = K^2$. At the end of the paper the author discusses the objections of A. N. Kolmogoroff to his formula as originally presented [*C. R. Acad. Sci. URSS*, 1946, vol. 51, no. 7; vol. 52, no. 8].

J. V. Wehausen, USA

Incompressible Flow: Laminar; Viscous

(See also Revs. 1452, 1483, 1485, 1486, 1487, 1519, 1520, 1531, 1565, 1566, 1576, 1578, 1579)

1495. **K. H. Grossmann, "Flow through blade grills (Strömungen durch Schaufelgitter),"** *Schweiz. Bauztg.*, July 31, 1948, vol. 66, pp. 429–430.

This paper considers the potential flow through a cascade arrangement of turbine blades. According to Traupel [*Proc. int. Congr. appl. Mech.*, Paris, 1946] it is sufficient to know only one potential flow through a given cascade in order to calculate the flow for an arbitrary angle of incidence. This has been done by conformal transformation when the single known flow is determined by means of the electrolytic tank method.

P. N. Brandt-Møller, Denmark

1496. **R. Miche, "Determination by a variational principle of movement of viscous fluids when the movement is not slow (Détermination par un principe variationnel du mouvement non lent des fluides visqueux),"** *Rev. gén. Hyd.*, 1947, vol. 13, Sept.-Oct., pp. 227–236; Nov.-Dec., pp. 295–300.

The equation satisfied by the stream function ψ in a two-dimensional motion of viscous incompressible liquid (density ρ, coefficient of viscosity μ) is found by equating to zero the variation of the integral throughout the field of the function

$$\rho(\psi_x\psi_{xt} + \psi_y\psi_{yt}) + \mu[4\psi^2_{xy} + (\psi_{yy} - \psi_{xx})^2] + \lambda[\partial/\partial t + \psi_y\partial/\partial x - \psi_x\partial/\partial y - (\mu/\rho)(\partial^2/\partial x^2 + \partial^2/\partial y^2)](\psi_{xx} + \psi_{yy})$$

where subscripts indicate partial differentiations.

The method is applied to the calculation of the dissipation of energy in some water waves of finite amplitude.

W. R. Dean, England

1497. **K. Bammert and J. Schoen, "Flow of liquids through rotating hollow shafts (Die Strömung von Flüssigkeiten in rotierenden Hohlwellen),"** *Z. Ver. dtsch. Ing.*, Mar. 1948, vol. 90, pp. 81–87.

The exit side of the steady flow of a liquid from a rotating hollow shaft is studied. Calculations show that, because of the rotation of the liquid, a mirror surface inclined to the axis of the shaft is formed. Since this surface also changes the cross section of the flow, the resulting pressure change must be taken into account in the equations of motion. The equations thus obtained can be solved for the shape of the mirror surface. Experimental results confirm the shape of the calculated surface, provided a simple device for rotating the liquid is installed at the entrance; otherwise, the rotation of the liquid would be limited to a thin boundary layer.

C. C. Lin, USA

1498. **G. A. Boogayenko, "On the theory of the hydrodynamic grid with thin vanes of arbitrary form"** (in Russian), *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*), July-Aug. 1948, vol. 12, pp. 453–462.

The author considers an incompressible potential two-dimensional flow past a straight cascade of infinitely thin slightly

curved profiles. He assumes that the chords of the profiles are either situated along the axis of the cascade or else are perpendicular to the axis. The flow is represented as due to a doublet at infinity and to vortexes distributed along the chords of the profiles. For the density of the vortex distribution the author derives a singular linear integral equation (that is, an integral equation with Cauchy principal values). Using complex variable methods this equation can be solved in closed form. The resulting formulas for the pressure distribution contain as a limiting case Munk's formulas. The method is then extended to profiles of small but not vanishing thickness. In that case the flow is considered as being produced by a doublet at infinity and by vortexes, sources, and sinks distributed along the chords.

Lipman Bers, USA

1499. M. S. Plesset and P. A. Shaffer, Jr., "Cavity drag in two and three dimensions," *J. appl. Phys.*, Oct. 1948, vol. 19, pp. 934–939.

Riabouchinsky's theory for cavitating flow past a flat plate is extended to symmetrical wedges of arbitrary angle. The extended theory is utilized for the numerical evaluation of the drag coefficient, pressure distribution, cavity width, and cavity length, values of which are tabulated for semiwedge angles ranging from 15 to 165 deg. The drag of cones of revolution is evaluated approximately, on the assumption that the pressure distribution along a generator of the cone is the same as that along the two-dimensional wedge of the same internal angle. A tabulation of the drag coefficients of right circular cones computed under the foregoing assumption is also presented.

John V. Becker, USA

1500. R. C. L. Bosworth, "An interpretation of the viscosity of liquids," *Trans. Faraday Soc.*, May 1948, vol. 44, pp. 308–317.

This is a paper on the physics of the liquid state. In particular, it is an attempt to obtain an expression for the viscosity of liquids based on the assumption that the transfer of momentum within the liquid occurs by means of the "phonons" of Brillouin. These phonons are carriers of momentum but not mass, which are visualized as being "particles," equivalent to the mechanical waves into which the Einstein and Debye theories of specific heat resolve the molecular motion. Brillouin's treatment considered only the effect of longitudinal waves.

The present paper argues that transverse waves of very short wave length are also present. An expression is developed for the viscosity of a phonon gas, in which both longitudinal and transverse waves are present. The mean free path of the transverse wave is assumed to be the same size as the distances between lattice discontinuities of the liquid. The expression thus derived is $\eta = 1.75 \times 10^{-7} M^{5/6}/(T^{1/2}\rho^{1/3}\beta_s)$. M is molecular weight, T is absolute temperature, ρ is density, and β_s is adiabatic compressibility. Encouraging agreement is obtained with experimental data for a large number of normal liquids.

Francis H. Clauser, USA

Compressible Flow, Gas Dynamics

(See also Revs. 1522, 1530, 1539, 1546)

1501. Y. Kuo, "Two-dimensional irrotational transonic flows of a compressible fluid," *Nat. adv. Comm. Aero. tech. Note*, no. 1445, June 1948, pp. 1–91.

This report is a modification and extension of the work of Tsien and the present author [*Nat. adv. Comm. Aero. tech. Note*, no 995] to cover flows with small circulation by the hodograph methods, in the subsonic and transonic speed ranges. In the hodograph plane the stream function and velocity potential are expressed as infinite series of trigonometric functions of ϑ and of hypergeometric functions of q, where ϑ is the azimuth of the velocity vector and q its magnitude. The difficulty involved in this method is finding the coefficients of these infinite series so that the flow in the hodograph plane corresponds to the desired flow in the physical plane. This is partially achieved by constructing a compressible flow in the hodograph plane which for a zero Mach number reduces to a known incompressible flow about a similar body.

The point $q = U$, $\vartheta = 0$ is a singularity in the hodograph plane for both the incompressible and compressible flows if the flow has a uniform velocity U at infinity. The known incompressible flow solution is represented mathematically by an expansion about the origin into an infinite series, which is convergent within the circle of radius U, and to which the series describing the compressible flow reduces for a zero Mach number. The series for the compressible flow outside of this circle may be obtained by analytic continuation or by use of the known character of the singularity in the incompressible flow. However, the author shows that the character of the singularity at $q = U$, $\vartheta = 0$ remains unchanged by compressibility only if the ratio of specific heats of the fluid is -1. In this report a method of allowing for this change in the character of the singularity is given.

The procedure is applied to the flow about an elliptic cylinder of thickness ratio 0.60 with a free-stream Mach number of 0.60, both with and without circulation. The highest local Mach number is 1.24, which is not sufficiently high, so that limiting lines appear. The pressure distribution given by this exact analysis is compared with the results obtained from application of the Glauert-Prandtl and the Kármán-Tsien pressure-coefficient corrections to the incompressible flow over approximately the same body. The discrepancies between the exact and approximate results demonstrate the invalidity of these approximate methods if the body is thick and/or if there is a supersonic region in the flow.

Paul A. Libby, USA

1502. W. James Orlin, Norman J. Lindner, and Jack G. Bitterly, "Application of the analogy between water flow with a free surface and two-dimensional compressible gas flow," *Nat. adv. Comm. Aero. tech. Note*, no. 1185, Feb. 1947, pp. 1–53

By passing a shallow flow of water between two-dimensional walls geometrically similar to the walls bounding the corresponding compressible gas-flow case various flow conditions, including pressure coefficients, shock-wave patterns, blocking effects, etc., can be calculated for the gas-flow case. Tests were run using this analogy as applied to the flow about circular cylinders of various diameters at equivalent subsonic velocities extending into the supercritical range. Data and photographs are presented and it is shown that reasonably satisfactory agreement of pressure distributions and flow fields existed between water and air flow about corresponding bodies.

The limitations and conditions of the analogy are discussed and the various analogous parameters listed. The apparatus and techniques used are described and criticized. The effect of varying certain parameters is studied and it is shown that the effect of the depth of the water is very pronounced. Flow conditions around the cylinders including the asymmetric and nonsteady formation of shock waves at supercritical speeds are discussed in detail.

E. Arthur Bonney, USA

1503. C. B. Cohen, "Influence of leading-edge suction on lift-drag ratios of wings at supersonic speeds," *Nat. adv. Comm. Aero. tech. Note*, no. 1718, Oct. 1948, pp. 1–27.

A method based on linearized theory is presented for calculating the theoretical suction force at the subsonic leading edges of a

family of wings at supersonic speeds. It is an extension of the method of von Kármán and Burgers for dealing with the singularity in velocity which occurs at the leading edge of thin wings at subsonic speeds. The method is used to determine the optimum sweepback angles for the tips of trapezoidal wings, and to determine the effect of the curvature of the tip contour on the lift-drag ratio of wing regions influenced by the tip. The effect of skin friction is included. The possible gain in lift-drag ratio from a proper tip design of trapezoidal wings increases as the sweepback of the wing is increased. Results indicate that appropriately curved tip boundaries will give higher lift-drag ratios in the region affected by the tip than the best trapezoidal wing.

M. J. Thompson, USA

1504. **Vera Huckel, "Tables of hypergeometric functions for use in compressible-flow theory,"** *Nat. adv. Comm. Aero. tech. Note*, no. 1716, Oct. 1948, pp. 1–13.

This paper tabulates various hypergeometric functions for air which define particular solutions of Chaplygin's differential equation in the hodograph method for plane potential compressible flows. In the preparation of the tables, the adiabatic index of the air was taken at 1.4. The tables should prove to be an aid in the calculation of auxiliary functions required in the solution of such problems.

John E. Goldberg, USA

1505. **I. A. Keebel, "Exact solutions of two-dimensional vortical flow equations of gas dynamics"** (in Russian), *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*), Jan.-Feb. 1947, vol. 11, pp. 193–198.

The author considers the equations of two-dimensional vortical flow of a compressible fluid. x, y, u, v, p, ρ, ψ denote the Cartesion co-ordinates in the physical and hodograph planes, the pressure, the density, and the stream function, respectively. If one introduces x and ψ as independent variables, one obtains for the remaining five quantities the equations

$$p^{1/\kappa} = \rho\vartheta(\psi),\ {}^1/_2(u^2 + v^2) + \kappa(\kappa - 1)^{-1}\vartheta_p{}^{(\kappa-1)/\kappa} = i_0(\psi),$$
$$\partial y/\partial x = v/u,\ \partial y/\partial\psi = 1/(\rho u),$$
$$\partial p/\partial\psi = -\partial v/\partial x,\ \kappa = c_p/c_v \text{ is a constant} \ldots [A]$$

The author introduces the function $\chi = \int(pdx - vd\psi)$, makes the assumption that i_o = const, and writes $\chi = -H(\psi)x^{-(\kappa-1)/(\kappa+1)}$. By formal computation it follows that

$$\vartheta[(\kappa-1)\ (\kappa+1)^{-1}H]^{-1/\kappa} = {}^1/_2(\kappa + 1)H'',$$
$$H'(H'^2 + HH'')' = -(\kappa - 1)H''(H'^2 + HH'')^{-\kappa/(1+\kappa)}.$$

From these equations the author obtains as a solution of the Equations [A]

$$\tilde{y} = \int[m^{2(\kappa-1)/(\kappa+1)} - 1]^{-1/2}dm,\ \tilde{x} = \eta m(\tilde{y}),$$
$$u^2 = 2i_0(1 - m^{-2(\kappa-1)/(\kappa+1)}),\ v = (2i_0)^{1/2}m^{2/(\kappa+1)}\tilde{x}^{-1}$$

where $x = x/L$, $\tilde{y} = y/L$, $L = (2i_0)^{-1/2(\kappa+1)/(\kappa-1)}\ C^{1/(\kappa-1)}$

These formulas permit determination of the streamlines (in the physical plane) of a flow which is partially subsonic, partially supersonic. The author shows that his result permits determination of a flow with a strong shock. The method can also be used to determine axially symmetric flows with vorticity.

Stefan Bergman, USA

1506. **R. von Mises and M. Schiffer, "On Bergman's integration method in two-dimensional compressible fluid flow,"** *Advances in Applied Mechanics*, Academic Press, Inc., New York, 1948, vol. 1, pp. 249–285.

Bergman's method, giving solutions of elliptic equations with no boundary conditions prescribed, is presented in Part I for two-dimensional isentropic flows. The problem is reduced to the equation $\Delta\psi^* + f(\lambda)\psi^* = 0$, where λ is a given function of the flow speed, f another given function, and $(1 - M^2)^{-1/4}\rho^{1/2}\psi^*$ is the stream function. The Chaplygin group of solutions does not exist in the realistic case of singular ψ^*, and Bergman sets $\psi^* = \Sigma g_n G_n$ where g_n is harmonic in λ and θ, and G_n depends on λ only. If $G_0 = 1$, $G'_{n+1} = G''_n + fG_n$ and $2\partial g_n/\partial\lambda = -g_{n-1}$, ψ^* is a solution. A set of g_n can be obtained as real parts of $\phi_n = -{}^1/_2 \int\phi_{n-1}(\zeta)d\zeta$. The series for ψ^* converges absolutely and uniformly in any closed subdomain of $|\theta| < 3^{1/2}\lambda$, but not outside of it.

At $M = 1$ the G_n are infinite, and a different representation is needed for the transonic case. Bergman puts $G_n = c_n T^{-3n}r_n(T)$ with $T^2 = 1 - M^2$. Recursion formulas for c_n and r_n are developed. r_n turns out to be a sum of an $(n - 2)$-degree polynomial in log T and a power series in T (r_1 and r_2 being regular). The computations are feasible.

Part II deals with a fictional gas yielding $f = C/\lambda^2$. Here ψ^* comes out regular in the whole subsonic region and is given by the real part of $\int\phi'_0(t)H[\alpha, \beta, \gamma;\ (2\lambda)^{-1}(\zeta - t)]dt$ where H is a hypergeometric function determined by C. Thus any incompressible stream function $g_0(\lambda, \theta)$, the real part of $\phi_0(\zeta)$, produces a set of stream functions for compressible flows. By choosing C and γ the equation of state of the real gas can be approximated for a prescribed region, even the transonic one. Graphs show how favorably this approximation compares with the Kármán-Tsien approximation.

A. W. Wundheiler, USA

1507. **R. Sauer, "General characteristics of the flow through nozzles at near critical speeds,"** *Nat. adv. Comm. Aero. tech. Memo.*, no. 1147, June 1947, pp. 1–20 (transl. from *Dtsch. Luftfahrtforsch. Forschungsber.*, no. 1992).

The characteristics of the position and form of the transition surface through the critical velocity are computed for flow through flat and round nozzles from subsonic to supersonic velocities. Corresponding computations are carried out for the flow about profiles in the vicinity of sonic velocities.

Approximate formulas are developed for the position and curvature of the critical curve for transition through the critical velocity in the case of flat and round Laval nozzles. Corresponding approximation formulas are derived for the flow through flat nozzles with curved axes to obtain information on the variation of the critical curve for profile flows with local supersonic regions.

The results are compared with those obtained from more exact formulas and are shown to be in close agreement.

Nicholas Di Pinto, USA

1508. **F. I. Frankl, "Influence of the acceleration of slender bodies of rotational symmetry upon the resistance of the gas,"** *Hdqtrs. Air Mat. Comm. Dayton Transl.*, no. A9-T-19, 1948, pp. 1–11 [transl. from *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*), 1946, vol. 10, pp. 521–524].

The author obtains an approximate solution of the wave equation for an accelerated slender body of revolution by considering the body replaced by a source distribution along the axis of the body. The boundary conditions at the surface of the body are satisfied to the order of the thin-body approximation. The pressure distribution over the body is obtained and compared with the distribution for steady supersonic flight. From this comparison the relative increase in pressure due to acceleration is shown to be of the order bl/V^2 where b is the acceleration, l the length of the body, and V the velocity. It is concluded that at transonic velocities acceleration up to 100g will produce only negligible additional pressures. A numerical example is included.

J. M. Wild, USA

1509. G. N. Ward, "The approximate external and internal flow past a quasi-cylindrical tube moving at supersonic speeds," *Quart. J. Mech. appl. Math.*, June 1948, vol. 1, pp. 225–245.

The approximate aerodynamic force and moment coefficients resulting from the fluid pressure of a supersonic flow past a cylindrical tube of nearly constant radius at small incidence have been calculated for the outside and inside of the tube for a length $(M_0{}^2 - 1)^{1/2}$ times the diameter of the tube, when M_0 is the Mach number of the undisturbed flow. The solution was obtained by applying the Heaviside operational method to the linearized differential equation. The results are given in a form suitable for computation.

The distribution of the velocity components inside the tube has been examined using the linear theory. It was found that singularities and discontinuities occur in these velocity components or in their derivatives, corresponding respectively to a discontinuous change in the slope of the meridian section of the tube or in the curvature of the streamlines bounding the fluid entering the tube.

C. T. Wang, USA

1510. S. Sherratt and J. W. Linnett, "The determination of flame speeds in gaseous mixtures," *Trans. Faraday Soc.*, Aug. 1948, vol. 44, pp. 596–608.

The assumptions made in the determination of flame speeds in many early investigations are stated and criticized one by one. The shortcomings of these approximations have been pointed out by Lewis and von Elbe who remedied the situation by experimentally determining the streamline shapes before computing the flame speed.

The authors present experimental evidence to show that, while the method of Lewis and von Elbe undoubtedly corrects for earlier errors, it involves a considerably more elaborate technique than is necessary. The authors take a shadow picture of the flame, which shows a flame front well inside of the luminous flame and of the curved region of the streamlines. Measurements of the shadow flame front and the assumption of laminar flow yield flame speeds in good agreement with those of Lewis and von Elbe. The experimental results for several mixture velocities and initial temperatures are shown, and the internal consistency of the measurements is discussed.

Howard W. Emmons, USA

1511. S. F. Shen, "Hypersonic flow over a slender cone," *J. Math. Phys.*, Apr. 1948, vol. 27, pp. 56–66.

The similarity laws for hypersonic flow developed by H. S. Tsien are applied to obtain a numerical solution for the hypersonic flow over a slender cone. The axially symmetric hypersonic flow over the cone is equivalent to the propagation of cylindrical waves from a uniformly expanding circular cylinder. The solution of this problem is analogous to G. I. Taylor's solution for uniformly expanding spherical waves. The numerical solutions of these equations are then taken so as to satisfy also the Rankine-Hugoniot shock-wave relations and provide a unique solution for this assumption.

A comparison with the Taylor-Maccoll numerical solution for the surface pressures on a cone shows good agreement between the hypersonic solution and that for a slender cone at the higher Mach numbers.

As the product of the free-stream Mach number and the cone nose angle approaches infinity, the hypersonic solution is shown to give a surface pressure coefficient only 4.5 per cent greater than that obtained by von Kármán for the simple case of hypersonic flow with a Γ value of unity.

E. V. Laitone, USA

1512. J. C. Evvard, "A linearized solution for time-dependent velocity potentials near three-dimensional wings at supersonic speeds," *Nat. adv. Comm. Aero. tech. Note*, no. 1699, Sept. 1948, pp. 1–35.

In previous publications [*Nat. adv. Comm. Aero. tech. Notes*, no. 1382, 1947, and no. 1585, 1948] the author has presented a valuable method for the calculation of steady-state velocity potentials of thin finite wings at supersonic speeds. With the aid of source potentials alone the inversion of the double integral equation arising in lifting-surface theory is accomplished for a large class of planforms.

The present report uses the same general approach to derive the velocity potential for wings in nonsteady motion. The method is illustrated by evaluating the upwash over the tip of an arbitrary plan boundary wing having a supersonic and subsonic leading edge. A specific example deals with the load distribution on a wing whose effective angle of attack varies linearly with time. It is pointed out that the method is also applicable to transient problems arising in the evaluation of loads on a wing entering a gust of given structure.

Max A. Heaslet, USA

1513. S. Yuan, "The flow of compressible fluid past quasi-elliptic cylinders at high subsonic speeds" (in English), *Sci. Rep. Nat. Tsing Hua Univ. Ser. A*, Apr. 1948, vol. 5, pp. 29–51.

A compressible-flow stream-function ψ can be derived from that of an incompressible one, say $\psi = \Sigma_m [A_1(Q/Q_0)^m + B_1(Q/Q_0)^n] \sin (m\theta + \epsilon_m)$, Q being the incompressible flow speed, by the familiar Chaplygin process of replacing Q/Q_0 by $qF(n, \tau)/q_0F(n, \tau_0)$, where F is a hypergeometric function and $\tau = q^2(\gamma - 1)$. The author extends this procedure to negative powers of Q/Q_0.

This modified procedure is then applied to a plane flow parallel to one of the two axes of symmetry of an obstacle. The convergence of the corresponding expansion for the compressible ψ is investigated. This expansion is specialized for a parent incompressible flow past an ellipse, transformed for better convergence when q is close to the undisturbed speed q_0, and the quality of the convergence investigated. The compressible boundary streamline is a distorted ellipse which is computed, together with its adjacent streamlines, and shown in diagrams. Hodograph diagrams, and tables and graphs of the several functions involved are given.

A. W. Wundheiler, USA

1514. M. Holt, "The behaviour of the velocity along a straight characteristic in steady irrotational isentropic flow with axial symmetry," *Quart. J. Mech. appl. Math.*, Sept. 1948, vol. 1, pp. 358–364.

Under the title assumptions the hodograph of a straight characteristic is an ellipse. (If the velocity is constant on it, this velocity must be parallel to the axis of symmetry.) The hodograph equations along a straight Mach line (of slope T) can be integrated explicitly, yielding the following relation between the distance r from the axis and the tangent t of the Mach angle

$$r = At^{1-k^2}(T \pm t)^{\alpha}[1 + (1 + k^2)t^2]^{\beta} \exp [\pm \delta \tan^{-1} (1 + k^2)^{1/2}t]$$

where A is an integration constant, $1 + 2/k^2$ is the ratio of the specific heats, $T = \tan \epsilon$, and α, β, δ are functions of k and T only.

Five cases are distinguished according to the values of ϵ, and the distribution of the velocity along the straight Mach line is qualitatively discussed. In three of these cases the velocity is not single-valued. The question whether the Mach lines adjacent to a straight Mach line must be also straight, so important in two-dimensional flow, is not brought up in the paper.

A. W. Wundheiler, USA

1515. **S. A. Schaaf, "Zonal combustion in tubes,"** *Quart. appl. Math.*, Oct. 1948, vol. 6, pp. 257–266.

This paper is an outgrowth of work on jet devices by the author and J. K. L. MacDonald ["A gas dynamical formulation for waves and combustion in pulse jets," Applied Mathematics Group, New York University, Rep. 151]. In this study of gas combustion it is assumed that the combustion extends over a definite layer, moving with time through the gas. The author confines himself to the problem of gas combustion in a half-open tube. For this case the author finds expressions for the gas pressure, flame-front position, and gas-flow velocity as functions of time.

The results are obtained by using perturbation methods to give approximate solutions for the nonlinear partial differential equations describing the progress of the combustion. The expansion is made in terms of a parameter which is proportional to the average rate of energy release during combustion. Principal and first-order terms of this expansion are given. Three important physical parameters appear in the approximate solutions. They are: (1) The rate of energy release during combustion, (2) the velocity of progress of the burning region into the unignited gas, and (3) the duration of burning of a given gas layer.

Benjamin Epstein, USA

1516. **R. E. Meyer, "The method of characteristics for problems of compressible flow involving two independent variables,"** *Quart. J. Mech. appl. Math.*, June 1948, vol. 1, pp. 196–219.

This paper constitutes a lucid, though concise, exposition of the use of the method of characteristics in problems of nonviscous adiabatic compressible flow. The mathematical development starts with the usual hydrodynamic equations in two-dimensional curvilinear orthogonal co-ordinates, valid for either plane or for axially symmetric flow in which there is no circulation about the axis. Using these general co-ordinates, the author derives the equations of the characteristics on which a method of numerical integration is based. This method is successively particularized by the assumptions of a perfect gas, uniform energy, and then uniform entropy. Next, a technique for handling shocks in pure supersonic fields is illustrated.

The final sections are devoted to unsteady flow symmetric about a plane, straight line or point. The entropy is assumed to be uniform throughout space. Certain similarities of treatment between the steady and unsteady cases are discussed.

Appendix I concerns the regularity of the orthogonal co-ordinate systems employed. Appendix II, by S. Goldstein, deals with the role of the axis in axially symmetric flow.

H. G. Elrod, Jr., USA

Turbulence, Boundary Layer, etc.

(See also Revs. 1487, 1488, 1497, 1540)

1517. **Hugh L. Dryden, "Recent advances in the mechanics of boundary-layer flow,"** *Advances in Applied Mechanics*, Academic Press Inc., New York, 1948, vol. 1, pp. 1–40.

The following topics are covered in this highly informative review (the numbers in parentheses indicate the numbers of papers listed in the bibliography at the end of each section):

Laminar flow in boundary layers, including three-dimensional problems and compressibility effects (45 papers).

Stability of laminar boundary-layer flow. The Tollmien-Schlichting theory of unstable waves is reviewed in connection with G. I. Taylor's work on free-stream turbulence and the Schubauer-Skramstad studies at the National Bureau of Standards. The relation of these waves to transition and the effects of curvature, pressure gradient, and compressibility are reviewed up to 1946 (23 papers).

Boundary-layer suction. This question is treated very briefly although 15 papers are mentioned in the bibliography.

Turbulent flow in boundary layers. This is the most detailed account, and the author's fundamental contributions have not been neglected. The empirical methods of Buri-Gruschwitz are described and followed by an exposition of the developments proceeding from Reynolds theory of turbulent stress (Prandtl, von Kármán, Nevzglyadov). A careful survey of the work and results of the National Bureau of Standards done by Dryden and his associates is then given. It contains a discussion of the experimental arrangement, numerous graphs, and some insights into the physical mechanism of boundary-layer turbulence (13 papers).

An additional bibliography on drag calculations (10 papers) and flight tests on boundary layers (4 papers) completes this article.

A. W. Wundheiler, USA

1518. **M. Tournier and M. Bassière, "A solution of the boundary-layer equations (Une solution des équations de la couche limite),"** *Rech. aéro. Paris*, July 1948, no. 4, pp. 67–72.

The authors give a solution of the boundary-layer equations by interpreting the boundary layer as a transient phenomenon with respect to the fluid. From this, a function that gives the velocity distribution in the boundary layer is determined for an incompressible fluid. They find that a solution much more satisfactory than the Blasius series is represented by the incomplete gamma function of order three. The values of this function for its arguments up to 1.7 are tabulated. It is shown both by curves and by numerical tabulation that the new solution and that of Blasius never deviate from each other by more than 3 per cent. The solution is obtained by the application of the Laplace transformation. The authors thus verify the Blasius solution by a more formal method.

Ahmed D. Kafadar, USA

1519. **M. Ledinegg, "The mechanism of turbulence (Der Mechanismus der Turbulenz),"** *Öst. Ingen.-Arch.*, Mar. 1948, vol. 2, no. 3, pp. 244–260.

By postulating a simple mechanism of turbulence in the turbulent flow of a viscous incompressible fluid through a cylindrical conduit, expressions for the average velocity profile are derived. It is assumed that vortex rings are generated in random fashion at the walls of the conduit. Subject to the lift and drag forces on the vortex cores the vortexes move radially inward as well as downstream. Near the axis of the conduit the vorticity is assumed to die away by cancellation of vortexes of opposite rotation. Detailed force and energy balances yield a differential equation for the average velocity as a function of the radius. This is integrated to give a logarithmic velocity profile in the main stream and a three-halves power parabolic profile in the neighborhood of the tube axis. Stephen H. Crandall, USA

1520. **M. Ray, "On a type of nonstationary turbulent wake"** (in English), *Bull. Calcutta math. Soc.*, Sept. 1947, vol. 39, pp. 139–142.

The author investigates a hypothetical turbulent wake behind a symmetrical cylinder, subject to exponential decay. The wake must be called hypothetical, as it is not clear what causes this decay. The velocity parallel to the mean flow is supposed to be proportional to $\exp(-Ct)$, the mixing length to $\exp(Ct)$, t being the time, and C a constant. The author introduces assumptions about the mixing length and velocity analogous to those used for the wake in steady state.

Choosing a special value of the constant C in the decay factors mentioned above, the steady factor of the velocity distribution takes the same form as the solution in the steady case. For the velocity of the mean stream the transient factor expresses a progressive decay upstream. One difficulty which the author himself emphasizes is that the edge of the wake seems to be independent of time, while the mixing length increases with time.

The axially symmetric case behind a body of revolution is treated along the same lines as the two-dimensional one. The momentum transfer and vorticity transfer theories lead to two differential equations. E. Abody-Anderlik, Hungary

1521. François N. Frenkiel, "Measurement of the turbulent diffusion of the natural wind in the vicinity of the earth's surface (Mesure de la diffusion turbulente de vent naturel dans le voisinage du sol))," *C. R. Acad. Sci. Paris*, Jan. 13, 1947, vol. 224, pp. 98–100.

The author describes certain results which have been obtained in the study of atmospheric turbulence. Let x_h, y_h, z_h be the co-ordinates at the time $t + h$ of a particle which passes the origin of the diffusion at the moment t. The quantities $n_x^* = {}^1/_2 d\overline{(x_h - h\bar{u})^2}/dh$, $n_y^* = {}^1/_2 d(\overline{y_h^2})/dh$, etc., are called by the author "coefficients of turbulent diffusion." Using an equation of Kampé de Fériet [*Ann. Soc. Sci. Brux. Ser. I*, 1945, vol. 59, p. 145] he concludes that

$$n_y^* = \overline{v'^2}\int_0^h R_{tL}^{v}(s)ds, \quad n_z^* = \overline{w'^2}\int_0^h R_{tL}^{w}(s)ds$$

where $R_{tL}^{u}(h)$, $R_{tL}^{v}(h)$, $R_{tL}^{w}(h)$ are coefficients of correlation of the systems of Lagrange. For $h \longrightarrow \infty$ the coefficients n_y^*, n_z^* become $\nu_y^* = \overline{v'^2}\, L_t^{v}$, $\nu_z^* = \overline{w'^2}\, L_{tL}^{w}$, that is to say the coefficients of viscous turbulence. Here $L_{tL} = \int_0^\infty R_{tL}(s)ds$. For small h, $n_y^* = \overline{v'^2}h$, $n_z^* = \overline{w'^2}h$.

In order to determine the ratio between the transverse turbulent viscosity, $(\overline{v'^2})^{1/2}/\bar{u}$, and the vertical one, $(\overline{w'^2})^{1/2}/\bar{u}$ the author uses the equations of Kampé de Fériet and, in particular, an asymptotic formula which gives the average concentration of particles emitted by a point source. He further shows that the curve limiting the locus of the particles in a plane x = const is an ellipse, and that the ratio of the diameters of this ellipse is $D_y/D_z = (\nu_y^*/\nu_z^*)^{1/2}$. In experiments which have been carried out the ratio between the horizontal and vertical diameters of the ellipse varies between 1.43 and 1.9. Stefan Bergman, USA

1522. L. M. Bollinger and D. T. Williams, "Effect of Reynolds number in the turbulent-flow range on flame speeds of Bunsen-burner flames," *Nat. adv. Comm. Aero. tech. Note*, no. 1707, Sept. 1948, pp. 1–29.

The authors present data obtained in 1944-1945 on flame speeds in gases issuing from long straight pipes which would, in the absence of flame, produce fully developed turbulent flow. Since definition of flame-front area and hence of flame speed is difficult for turbulent flows, the basic variable studied is flame height which is then related to flame area by an empirical correlation. Within the accuracies of the measurements and of this correlation it is found for mixtures consisting of air and each of three fuels (acetylene, propane, and ethylene) that $(u_t/u_n) = 0.18\ d^{0.26}Re^{0.24}$ where u_t is the flame speed for a burner of diameter d, burner Reynolds number Re, and u_n the maximum laminar flame speed. In the studies d ranges from 0.626 to 2.843 cm and Re from 3,000 to 35,000. Bruce L. Hicks, USA

1523. G. F. Djang, "A kinetic theory of turbulence" (in English), *Chin. J. Phys.*, June 1948, vol. 7, pp. 176–191.

This paper is based on an analogy between the theory of turbulence and the kinetic theory of gases. The author believes that the square of the Reynolds number of the turbulence $(u'\lambda_m/\nu)^2$ is analogous to the temperature of a gas, which he regards as a dimensionless quantity. It is assumed that turbulence flows from a region where the Reynolds number of the turbulence is high to the regions of lower Reynolds number. The Boussinesq eddy viscosity concept is used, but it is assumed that the eddy viscosity equals $k\lambda_m^2 u'/\nu$ rather than $k_1\rho\lambda_m u'$, as is more common.

When considering particular examples other arbitrary assumptions are introduced, for example that the scale of the turbulence in a circular pipe of radius a is equal to $\alpha_1 y_1 + \beta_1 y_1^2/a$ where y_1 is the distance from the wall and α_1 and β_1 are constants.

Hugh L. Dryden, USA

1524. Elizabeth Hahneman, J. C. Freeman, and M. Finston, "Stability of boundary layers and of flow in entrance section of a channel," *J. aero. Sci.*, Aug. 1948, vol. 15, pp. 493–496.

In this paper the simplified stability theory of C. C. Lin is applied to the following conditions of fluid flow: (1) The stability of flow in the entrance section of a two-dimensional channel. (2) The influence of pressure gradient on the stability of boundary-layer flow. (3) The influence of suction on the stability of boundary-layer flow.

For case (1) it is shown that the critical Reynolds number for entrance flow in a two-dimensional channel decreases monotonically from infinity at the channel entrance to a constant value corresponding to parabolic distribution at a large distance along the channel.

For cases (2) and (3) it is shown that the results of Lin's approximate method compare favorably with those of considerably more elaborate methods. Frank L. Wattendorf, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 1503, 1512, 1529, 1534)

1525. G. A. Crocco, "Passing through the sonic barrier," *Aircr. Engng.*, Aug. 1948, vol. 20, pp. 220–226, 248.

A simplified analysis is made of the supersonic turbojet and ramjet assuming first adiabatic compression and expansion, and later introducing a factor to account for duct losses. Results are presented in the form of a thrust coefficient. The drag of airplanes in supersonic flight is then considered, using approximate results of Ackeret, von Kármán and Busemann.

Combination of the results of the first and second parts of the paper leads to conclusions regarding the performance of supersonic aircraft. It is concluded that supersonic flight is practicable, aside from the difficulties expected in passing through the sonic region. The third part of the paper is a proposal for a lift-producing jet engine, which would permit the elimination of wings, and thus possibly the avoidance of sonic difficulties. Following some analysis of this arrangement, there are presented some design considerations and numerical data relating to winged supersonic airplanes. W. R. Sears, USA

1526. Harvard Lomax, "Sideslip angles and vertical tail loads developed by periodic control deflections," *Nat. adv. Comm. Aero. tech. Note*, no. 1504, Jan. 1948, pp. 1–62.

Solutions of the lateral stability equations are given, yielding maximum sideslip angles and attendant rudder deflections in airplane motions produced by sinusoidal rudder and aileron deflec-

tions. Although the theory is based on linear variations of forces and moments with sideslip angle, methods are given for studying nonlinear effects. Twenty-seven airplane configurations are analyzed.

Three airplane maneuvers are considered: (1) ailerons locked, (2) ailerons applied to hold wings level, (3) ailerons applied to reduce roll. The locked-aileron maneuver is found to be most useful as a vertical tail-load criterion.

The theory of the locked-aileron maneuver is checked experimentally by flight test of a conventional carrier-based airplane. Theoretical comparison is made between the locked-aileron maneuver and two other dynamic maneuvers, the rolling pull-out and the rudder kick. One and one-half rudder cycles are found to produce tail loads of equivalent magnitude to those obtained in the rolling pull-out for certain configurations. One rudder cycle is found to produce more sideslip than that obtained from the rudder kick for all configurations. W. G. Cornell, USA

1527. **A. Pope, "On airfoil theory and experiment,"** *J. aero Sci.*, July 1948, vol. 15, pp. 407–410.

There are thickness effects on the theoretical lift curve slope and aerodynamic center of an airfoil section, and the corresponding formulas are quoted. An incomplete discussion is then given of the effects of viscosity. An approximate method is suggested for estimating profile drag; no mention is made of the established and more accurate method described in *Rep. Memo. aero. Res. Counc. Lond.*, no. 1838. A. D. Young, England

1528. **A. Goodman and J. D. Brewer, "Investigation at low speeds of the effect of aspect ratio and sweep on static and yawing stability derivatives of untapered wings,"** *Nat. adv. Comm. Aero. tech. Note*, no. 1669, Aug. 1948, pp. 1–34.

Low aspect ratios and large sweep angles introduce aerodynamic effects which generally are not amenable to theoretical treatment. Consequently, recourse must frequently be made to experimental information for extreme planforms. This report presents data on the effects of aspect ratio and sweep when varied independently, as disclosed by experiments on models having sweep angles of 0, 45, and 60 deg and aspect ratios of 1.34, 2.61, and 5.16. The effect of sweep upon static stability was found to decrease as the aspect ratio decreased.

For constant sweep, damping in yaw decreased generally with increase in aspect ratio. At moderate lift coefficients, however, this derivative changed sign for the swept-back wings. For unswept wings it was found that the rolling moment due to yaw was approximately proportional to the lift coefficient up to maximum lift. For the swept-back wings, the linear relation held only for small or moderate lift coefficients. John E. Goldberg, USA

Aerolasticity (Flutter, Divergence, etc.)

(See also Rev. 1448)

1529. **F. W. Diederich and Bernard Budiansky, "Divergence of swept wings,"** *Nat. adv. Comm. Aero. tech. Note*, no. 1680, Aug. 1948, pp. 1–32.

The aerodynamic load on an airplane wing varies with the square of the flight speed if the angle of attack is the same everywhere. Unfortunately the structural deflection due to the air load usually increases the angle of attack and therefore increases the air load further. The interaction between the air load and structural deflection becomes stronger at higher speed, until finally a "divergence" speed is reached such that with further increase in speed the structure will fail. In the swept wing this speed is due to both bending and torsion.

The author's assumptions are very simple: (a) Strip theory for calculating air load; (b) small elastic deflection; (c) simple bending and torsion theory and straight elastic axis. Despite such simple assumptions some interesting results are obtained: (1) The divergence speed drops rapidly as sweepforward increases to about 40 deg but wings with moderate or large sweepback cannot diverge. (2) The location of the elastic axis is found to affect the divergence speed most at low angles of sweep, where movement of the elastic axis forward (or center of pressure aft) raises the divergence speed. (3) The effect of wing taper is to increase the divergence speed of essentially unswept wings, and to decrease the divergence speed of wings with moderate and large angles of sweep in the case of the prescribed stiffness variation.

A few points need further investigation: (a) Divergence speed probably occurs at transonic or supersonic speed. Thus a better approximation is needed for calculating air load. (b) Plastic behavior of the wing has to be considered, particularly with shell-type structure. The divergence speeds based upon the present theory are probably high. (c) The extensive travel of the center of pressure from subsonic to supersonic velocity may have a great effect on divergence speed.

A few charts and approximate formulas suitable for obtaining quick estimates of the divergence speed are given. A few low-speed wind-tunnel tests of an untapered solid wind model appear to agree with the theory up to 40-deg sweepforward angle.

Chieh-Chien Chang, USA

1530. **J. W. Miles, "Harmonic and transient motion of a swept wing in supersonic flow,"** *J. aero. Sci.*, June 1948, vol. 15, pp. 343–346, 370.

The results of previous papers [*J. aero Sci.*, June 1947, vol. 14, pp. 351–358; Sept. 1948, vol. 15, pp. 565–568; Oct. 1948, vol. 15, pp. 592–598] are extended to the case of a yawed uniform wing whose leading and trailing edges are ahead of the Mach waves. Elementary solutions of the linearized potential equation for an oscillating source and line source are used. It is concluded that the nonsteady motion of this type of airfoil at Mach number M is equivalent to that of an unyawed airfoil having the same chord and chordwise velocity distribution in the flight direction, if the forces on the latter are reduced by a factor $\cos \sigma$ and its Mach number is taken as $M \cos \sigma$, where σ denotes the angle of yaw. The treatment of flutter of a swept wing is discussed in the light of this result. W. R. Sears, USA

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 1492, 1495, 1498, 1507, 1537, 1543, 1558)

1531. **A. J. Stepanoff, "Centrifugal and axial-flow pumps: theory, design, and application,"** John Wiley & Sons, Inc. New York, 1948. Cloth 6 × 9.25 in., 428 pp., 310 figs.

This book provides much needed modern information on radial, mixed, and axial-flow pumping machinery, and is of particular value to engineers engaged in pump design, selection, specification writing, and operation. The theoretical foundation, design applications, and operating characteristics are included for each general type of pumping equipment covered. The review and summary of fundamentals frequently lacks rigor and thorough understanding, but the author has made clear the essential and useful end criteria of major importance for applications.

The first four chapters include a normal treatment of the necessary fundamentals, including the flow phenomena due to friction and channel bends, Euler equations for flow through impellers, and approximate methods to determine the actual head

developed by an impeller. In addition, several types of vortex flows are treated but the stability of each type is not discussed. The approach from the vortex flow standpoint is the unique feature of the book which allows the author to treat radial, mixed, and axial-flow pump design on a common basis, and to develop a universal design chart.

Six chapters are devoted to hydraulic design procedures and information. An excellent treatment of important design constants in terms of specific speed is presented. Mixed-flow impeller vanes are designed on the basis of the usual cone development and the new method of "error triangles." The discussion of casings covers the effects of radial loads on the shaft and the desirability of double-volute constructions. Airfoil data are discussed in connection with axial-flow pumps having fixed or adjustable blades. An excellent chapter on cavitation combines elementary theory and available experimental information. All basic hydraulic design characteristics of the impeller are contained in one universal design diagram covering the range from 500 to 15,000 specific speed.

Four chapters cover mechanical features, including such items as disk friction, bearing and packing gland losses, axial thrust, shaft critical speeds, and problems associated with special purpose units such as hot oil and boiler feed pumps.

Operating performance is covered in about three chapters which form a contribution to the literature in the field. This information includes such items as complete four-quadrant steady-flow characteristics, unsteady or transient conditions during starting and stopping operations, information regarding vertical-shaft deep-well turbine pumps, axial-flow pumps, special drive means, and performance with viscous liquids.

Centrifugal-jet pump water pressure systems are treated in the last chapter. The methods of analysis are unique and provide a simple approximate means to determine the performance of the combined unit. Richard G. Folsom, USA

1532. L. Crocco, "The double-flow jet-propulsion turbine (Il turboreattore a due flussi)," *Monogr. sci. Aero.*, July 1947, no. 6, pp. 3–25.

The article describes a turbofan of the fully ducted variety, that is, one in which the fan is placed ahead of the compressor inlet. This device is analyzed and compared with the Campini jet and the turbojet from the standpoint of efficiency.

In the Campini jet, the compressor is driven by an engine which is entirely contained within the ducted flow. With this arrangement, all the heat that is not converted to mechanical work in the engine is added to the air in the high-pressure region downstream of the compressor, and the over-all characteristics of the jet are therefore independent of the efficiency of the driving engine. The efficiency of the turbojet is chiefly dependent on the free-stream temperature and on the compression ratio, and is quite sensitive to relatively slight changes of compressor or turbine efficiency. The analysis of the turbofan confirms the well-known economic advantage of this device over the turbojet at low speeds. After-burning reduces this advantage to a considerable extent. Mixing of the two flows should take place and possibly be completed before the expansion through the exhaust nozzle is started. Joseph V. Foa, USA

1533. W. A. Benser and J. J. Moses, "An investigation of backflow phenomena in centrifugal compressors," *Nat. adv. Comm. Aero. Rep.*, no. 806, 1945 (publ. in 1948), pp. 1–15.

In this report the layout and results of different tests on backflow in centrifugal compressors are described. The following three methods were used: Lampblack studies on a one-stage mixed-flow unit; tuft studies with woolen tufts mounted on the walls of the transparent inlet duct on a conventional radial compressor unit; and measurements with a Fechheimer tube and thermocouple at the impeller inlet of a unit with axial flow at the inlet.

The results of the tests show that the backflow increases with decreasing load coefficient (that is, ratio of volume flow to rpm). At high-load coefficients a small amount of backflow occurs in the region of the impeller blade tips, whereas the backflow covers the whole front housing and extends back into the impeller inlet passage and even into the inlet duct at small load coefficients. The measurements with the Fechheimer tube show that the axial velocity near the center of the inlet pipe remains practically constant when the volume flow at constant rpm is changed. That means that the angle of attack of the corresponding blade sections is not appreciably affected when the volume flow varies. Thus the backflow has a tendency to extend the range of surge-free operation.

A qualitative explanation of the backflow phenomena is given by considering the interaction of the following three pressure gradients: the pressure gradient due to the centrifugal force, the pressure gradient due to the changes in area of the impeller passages, and the pressure gradient due to the curvature of the impeller housing.

It must be pointed out that the results of this investigation are strictly valid only for the specific compressor types and flow conditions of the test installations considered. H. Haenni, USA

1534. Frank Whittle, "Development of the jet-propulsion gas turbine for aircraft," *Engng. J. Montreal*, **July 1947**, vol. 30, pp. **316–322.**

This paper covers the general theory of jet propulsion, and gives a brief historical outline of the stages in the development of the jet-propulsion gas-turbine engine for aircraft. It does not, however, deal with the matter as fully as some earlier papers [*Proc. Instn. mech. Engrs.*, 1945, vol. 152, p. 419; vol. 153, War Emergency Issue no. 12].

Special features and technical details of the individual components of various engines designed, tested and manufactured since 1941 are mentioned, and some interesting comparisons are made with the piston engine and propeller combination. The author gives his reasons for favoring centrifugal rather than axial compressors for gas-turbine engines. He briefly discusses some of the problems of combustion chambers, and concludes with an assessment of present and possible future developments of the turbojet engine.

The paper is illustrated not only by photographs of some existing engines and their components, but also by diagrams of various alternative arrangements of compressor, combustion chambers, and turbine, and by several graphs giving speed-power and range-speed curves for jet and piston engines.

A. H. Zaludová, Czechoslovakia

1535. F. N. D. Kurie, "Vacuum systems, seals, and valves," *Rev. sci. Instrum.*, Aug. 1948, vol. 19, pp. 485–493.

Design suggestions are given for valves, shaft seals, and gasketed joints intended for use in continuously pumped all-metal vacuum systems. Pressure instrumentation, leak-hunting techniques and maintenance details are described briefly. The methods discussed are applicable generally to systems operating below atmospheric pressure, and particularly in the range 1 to 10^{-6} mm of Hg absolute (2×10^{-2} to 2×10^{-7} psia). Commercial vacuum pump performance characteristics are given in another reference [H. M. Sullivan, "Vacuum pumping equipment and systems," *Rev sci. Instrum.*, Jan. 1948, vol. 19, pp. 1–15].

E. D. Kane, USA

Flow and Flight Test Techniques

(See also Revs. 1502, 1533, 1535)

1536. **D. W. Grover and R. A. P. Wertheim, "A new capillary viscometer,"** *Research Lond.*, Oct. 1948, vol. 1, pp. 618–624.

The viscometer described in this paper was developed in order to study the flow characteristics of a liquid whose rheological properties change slowly with time. The mathematical analysis is based on the assumption that the rate of flow is proportional to the Poiseuille constant and the pressure drop, and inversely proportional to the apparent viscosity. Two forms of apparatus based on this analysis are described. Experimental procedure and corrections are discussed.

P. C. Chu, USA

1537. **R. H. Essig, H. R. Bohanon, and D. S. Gabriel, "Jet diffuser for simulating ram pressure and altitude conditions on a turbojet-engine static test stand,"** *Nat. adv. Comm. Aero. tech. Note*, no. 1687, Aug. 1948, pp. 1–34.

The results of turbojet static test-stand investigations are presented in which a jet diffuser was employed utilizing the kinetic energy of the exhaust jet to lower the discharge pressure at the exhaust nozzle, and thereby to simulate ram-pressure ratios (engine-inlet to exhaust-chamber-pressure ratio) at a simulated pressure altitude. Simulated ram-pressure ratios up to approximately 2.4 at a simulated pressure altitude of 23,000 ft were obtained.

Data reduction factors and performance parameters from previous work by Newell D. Sanders ["Performance parameters for jet-propulsion engines," *Nat. adv. Comm. Aero. tech. Note*, no. 1106, 1946] are utilized to present corrected engine-performance curves.

These tests were run on a 1600-lb-thrust centrifugal-compressor-type turbojet engine with a $12^1/_2$-in-diam tail-pipe exhaust nozzle.

W. C. Nelson, USA

1538. **H. Matheson and M. Eden, "A highly sensitive differential manometer,"** *Rev. sci. Instrum.*, Aug. 1948, vol. 19, pp. 502–506.

The differential manometer described in this paper consists of a pair of circular nesting diaphragms, soldered along the rim. The distance in the central region between them varies with the difference between the internal pressure and the external pressure, and this is made to affect the resistance of an electrical circuit, measured by the usual means. The apparatus has a sensitivity of about 0.001 mm of mercury, and can be employed for pressures between 1 mm of mercury and 1 atm. Many details of construction and performance are furnished.

Duilio Citrini, Italy

1539. **H. J. Allen and W. G. Vincenti, "Wall interference in a two-dimensional flow wind tunnel, with consideration of the effect of compressibility,"** *Nat. adv. Comm. Aero. Rep.*, no. 782, 1944 (issued in 1948), pp. 1–30.

The paper presents a thorough study of wind-tunnel-wall corrections in the two-dimensional case. It takes into account the thickness and the camber of the airfoil, the influence of the wake, and the compressibility of the gas. In the usual manner the influence of the wall is obtained by the method of images. The study of the influence of the thickness of the body is based upon the considerations of Lock. The wake is approximated by a source whose strength is related to the drag coefficient by the requirement that the pressures far upstream and far downstream of the body in the flow with a wake and with a source are equal.

The presence of lift and of camber causes a vortex distribution along the body. The images of these vortexes produce a curvature of the flow in the vicinity of the profile, such that the pressure distribution obtained is that of an airfoil with a different camber.

Here the question arises as to how the flow in the tunnel should be related to the flow in free air. For this purpose the requirement is introduced that the first term in the expression for the lift distribution, which is the most important one with respect to the boundary layer, is the same in both cases. The angle of attack as well as the lift coefficient are corrected accordingly. The correction formulas for the moment coefficient are given. The effect of choking is then discussed. Finally a comparison with experimental results and correction formulas of other authors is made.

Gottfried Guderley, USA

1540. **R. B. Couch, "Notes on turbulence-stimulating devices used for model tests at the David Taylor Model Basin,"** *David Taylor Model Basin Rep.*, no. 662, Aug. 1948, pp. 1–8.

Although the upstream-rod and the sandpaper-strip methods of hastening boundary-layer transition in small Reynolds number towing-tank tests, as reported here, are of inconclusive value, this note gives the interesting news that hot-wire equipment is being developed for the study of velocity fluctuations in water.

Stanley Corrsin, USA

1541. **C. E. Janes, "Instruments and methods for measuring the flow of water around ships and ship models,"** *David Taylor Model Basin Rep.*, no. 487, Mar. 1948, pp. 1–29.

This is an operational description of three velocity measuring devices (two-directional Pitot-static tubes and a vane-type meter) which are used at the David Taylor Model Basin to determine the water flow around ship models.

Stanley Corrsin, USA

1542. **Ernest F. Fiock and Andrew I. Dahl, "The use of thermocouples in high-velocity gas streams,"** *J. Amer. Soc. nav. Engrs.*, May 1948, vol. 60, pp. 139–162.

This paper is a summary of the considerations involved in the application of thermocouples to the measurement of low and high-velocity gas stream temperatures. The first section of the paper deals with the factors which determine the accuracy with which the temperature of the thermocouple junction can be measured. The remainder of the discussion considers means of decreasing or of predicting the difference in temperature between the measuring junction and the gas whose temperature is measured.

In most thermocouple measurements of gas temperatures in gas turbines the major error is shown to be due to radiation from the thermocouple to the gas-duct walls. Experimental data are cited to show that a sheath of silver (or other metal of low emissivity) over the junction is more effective in reducing this radiation error than a conventional shield composed of three concentric cylinders.

Several thermocouple installations suitable for measuring the total temperature of high-velocity gas streams are presented and experimental means for determining the recovery factor of any temperature-measuring device are outlined.

F. E. Romie, USA

Thermodynamics

(See also Revs. 1443, 1510, 1515, 1522, 1532, 1534, 1555, 1569)

1543. A. J. Buchi, "Turbocharging and gas turbines," *J. Amer. Soc. nav. Engrs.*, Aug. 1948, vol. 60, pp. 261–291.

The author discusses the outstanding achievements in the design of turbo-charged Diesel engines and the newer improvements in their efficiency. The most substantial of them involve: (1) The use of two blowers, one driven by the Diesel engine itself, the other, in compound with the first one for higher loads, being an exhaust-gas-driven turbocharger; (2) the combustion method based on a suitable study of the combustion chamber, the fuel injecting system and the inlet and exhaust valve port areas; and (3) the efficiency of the blower and the turbine, both of the radial type.

These improvements have been obtained essentially for the blower, by a rational study of the diffuser; and for the turbine, generally a one-stage reaction turbine, by providing it with a suitable diffuser.

Finally, the author describes another power plant system conceived by him a long time ago, and resulting in a reduction of weight and fuel consumption. It consists of a Diesel engine operating as a gas producer for a gas turbine. The power supplied directly from the engine is exactly that needed to drive the charging and scavenging compressor. Carlo Ferrari, Italy

1544. E. Wirth, "The value of the heat pump for heating installations" (in English), *Sulzer tech. Rev.*, 1948, no. 1, pp. 29–41.

This article concerns the application of the heat pump to domestic and industrial heating and air conditioning. After giving a short history of the subject it discusses the economic aspects of the heat pump. Examples of several heat pump installations in Switzerland are given. It is stated that the coefficient of performance (the ratio of output to power input) of one plant is about 5.45. The article is mostly descriptive and claims that the heat pump can be made a valuable instrument of thermal economy for the future as well as in the present.

Ahmed D. Kafadar, USA

1545. R. M. Walker, "Variable specific-heat corrections for the efficiency of the basic internal-combustion thermodynamic cycle and their application to the constant-volume, constant-pressure, Diesel, and Humphrey pump cycles," *Phil. Mag.*, Aug. 1948, vol. 39, pp. 605–613.

A generalized gas cycle for internal combustion engines is analyzed for efficiency, primarily in terms of specific heats which vary linearly with temperature. The cycle consists of heating at constant volume and at constant pressure in succession, isentropic expansion to maximum volume, cooling at constant volume and at constant pressure in succession, and isentropic compression. An explicit statement is given for the efficiency of the generalized cycle in terms of volume and pressure ratios and the constants in the equations for specific heats.

Expressions are obtained for correction factors to be applied to the expressions for efficiency based on constant specific heats for three special cycles: constant-volume heating and cooling, constant-pressure heating and cooling, and constant-volume heating with constant-pressure cooling (the Humphrey pump cycle).

Considerable detail is given of the method of obtaining the desired data from the equations presented.

Joseph H. Keenan, USA

1546. E. T. Vincent, "Supercharging the internal combustion engine," McGraw-Hill Book Co., New York, 1948. Cloth, 6 × 9.2 in., 315 pp., 167 figs., $5.00.

The book is essentially a collection of design data on compressors, with discussion of surging in centrifugal superchargers, supercharger testing techniques, and the supercharged Diesel cycle. The text is based on notes that were used by the author in 1944 for a course on superchargers under the ESMWT program, and is intended for readers who are not directly connected with the development of superchargers. Because of the dearth of properly collected information on this subject, many will find the book useful, despite the inconsistencies and inaccuracies which it contains in its theoretical sections and even in the presentation of such basic concepts as those of adiabatic, isentropic, and polytropic processes. Joseph V. Foa, USA

Heat Transfer; Diffusion

(See also Revs. 1562, 1577)

1547. V. S. Pushkin, "On the question of heat conduction in solid bodies, III" (in Russian), *J. tech. Phys.* (*Zh. tekh. Fiz.*), Aug. 1948, vol. 18, pp. 1044–1050.

This paper, which follows two former publications of the same author [*J. tech. Phys.* (*Zh. tekh. Fiz.*), 1946, vol. 16, nos. 2 and 12], examines the problem of thermal conductivity in the case of fusion. The system considered is a semi-infinite homogeneous bar whose exterior cylindrical surface is insulated. The heat flow has the direction of the z-axis and is symmetric about it. The interface between the solid and liquid phase is assumed to be plane.

The process of conduction is expressed by two similar temperature (ϑ) equations, one for each phase. If an interface (of abscissa ξ) is present it is necessary to add the equation of the kinetics of the process. These equations are (r_m, latent heat of fusion; τ, time)

$$\frac{\partial\vartheta_i}{\partial\tau} = a_i\left(\frac{\partial^2\vartheta_i}{\partial r^2} + \frac{1}{r}\frac{\partial\vartheta_i}{\partial r} + \frac{\partial^2\vartheta_i}{\partial z^2}\right),\ i = 1, 2.$$

$$\frac{\partial\xi}{\partial\tau} = (\lambda_1 \operatorname{grad} \vartheta_1 - \lambda_2 \operatorname{grad} \vartheta_2)/\gamma_0 r_m.$$

The subscripts 1, 2 correspond to the solid and liquid phase. The boundary conditions are

$$\vartheta_1 = \vartheta_1(r, z) \text{ for } \tau = 0,$$

$$q_1 = q_1(r, z) \text{ for } \tau > 0,\ z = 0,$$

$$\lambda_2 \operatorname{grad} \vartheta_2 = \lambda_1 \operatorname{grad} \vartheta_1,$$

$$\vartheta_1 = \vartheta_2 = \vartheta_{\text{fusion}} \text{ for } z = \xi;$$

Since the equations must be invariant with respect to scale changes, certain relations between the scale factors ν are obtained (for instance $\nu_a\nu_\tau = \nu_1^2$); there are six such relations. It is stated that eight of these factors are determined by geometrical characteristics and physical properties of the material, and the remaining six are covered by the six relations mentioned.

Six criteria of similarity are thus obtained; the two of Fourier (one for each phase) for the boundary conditions; two for kinetics, one for the initial distribution of the temperatures, and one for the heat flow. The last two include functions depending on the boundary conditions. D. Jacovleff, Belgium

1548. K. Ludwig, "Heating of a wall in the starting of a heating plant (Das Aufheizen einer Wand durch eine anlaufende Heizanlage)," *Ingen.-Arch.*, 1947, vol. 16, no. 1, pp. 45–50.

In this paper the author solves essentially the equation of heat conduction for the one-dimensional case with the following boundary conditions

$$- \lambda(\partial\vartheta/\partial x)_{x=0} = q\,[1 - \exp(-ab^2t)],$$

$$- \lambda(\partial\vartheta/\partial x)_{x=\delta} = \alpha(\vartheta)_{x=\delta}$$

the initial temperature being zero. The above boundary conditions correspond to the case of a wall of thickness δ. The heat input to the inside surface is $q[1 - \exp(-ab^2t)]$, with heat loss from the outer surface into a medium at zero temperature. In the above expressions b and q are constants, λ is thermal conductivity, and a the thermal diffusivity of the wall, α is the heat transfer coefficient from the outside wall surface to the air at zero temperature.

The problem is first solved by the usual method of expressing ϑ as a product of a function of t by a function of x (Bernoulli's method). As an alternative the Laplace transform method is also applied to obtain the solution of the problem. Both methods are relatively simple and straightforward for the problem treated.

Ahmed D. Kafadar, USA

1549. **C. S. Chow, "The thermal conductivity of some insulating materials at low temperatures,"** *Proc. phys. Soc. Lond.*, Sept. 1948, vol. 61, pp. 206–216.

Measurements were made of the thermal conductivity of some insulating materials over a range of temperatures from 18 to -180 C. The insulating material was arranged in cylindrical form so that heat flowed radially outward. Precautions were taken to eliminate longitudinal heat flow near the ends of the cylinder. The radial temperature gradient was measured for finely granulated and loosely packed fibrous materials, while only the mean conductivity was observed for coarsely granulated materials.

Curves showing the thermal conductivity as a function of the temperature are given for granulated slab cork, granulated vermiculite, a sea-weeds product, sawdust, cotton wadding and slag wool. The effect of the variation of bulk density of some of these materials on the conductivity-temperature relation is also given. A comparison is made of these results at low temperatures with those available at moderate temperatures on similar materials.

Joseph Kaye, USA

Theoretical and Experimental Methods

(See also Revs. 1504, 1535)

1550. **N. Minorsky, "Modern trends in nonlinear mechanics,"** *Advances in Applied Mechanics*, Academic Press Inc., New York, 1948, vol. 1, pp. 41–103.

This article is an abridgment of the first three parts of the author's *Introduction to Nonlinear Mechanics* (Edwards Brothers). The concepts and methods are described and illustrations (but almost no proofs) are given. The discussion is limited to one degree of freedom. A list of topics follows:

1 Topological methods. Motions are represented by graphs in the position-velocity plane organized into regions by means of closed graphs representing periodic motions. The stability status of a motion depends on the region where it begins. The index theorems of Poincaré and Bendixson are stated.

2 Analytical methods. Poincaré's method for equations $x' = ax + by + \mu f(x, y)$, $y' = cx + dy + \mu g(x, y)$. Small μ determines the periodic solutions if we know those at $\mu = 0$. It is based on truncation of power series of all the functions involved. Van der Pol's method applies to similar equations possessing solutions of form $x = a \cos t + b \sin t$ at $\mu = 0$, and seeks solutions of the same form with a, b dependent on t, μ. Fourier expansions are used. The Kryloff-Bogoliuboff method looks for solutions of form $x = a \sin(\omega t + \varphi)$ of the equation $\ddot{x} + \omega^2 x = \mu f(x, \dot{x})$ where a, φ are functions of t, μ. Fourier expansions are used again. Approximations of higher order are then touched upon.

3 The theory of subharmonic resonance (still in its infancy) is discussed for $\ddot{x} + x = \mu f(x, \dot{x}) + \lambda_0 \sin nt$. It is shown that for small μ, solutions $x = a_0 \sin t + b_0 \cos t + \lambda_0 (1 - n^2)^{-1} \sin nt$ exist, their stability conditions are determined. The vibration $a_0 \sin t + b_0 \sin t$ is subharmonic of order $1/n$ relative to the exciting force $\lambda_0 \sin nt$. The Rayleigh case of order $1/2$, treated by Mandelstam and Papalexi, is reviewed. Entrainment of frequency occurs when the frequency of the self-excited vibrations jumps suddenly to equality with the exciting frequency, as the latter tends toward a certain value. Van der Pol's theory is given. Parametric excitation occurs when vibrations in one parameter excite vibrations in others. The correlation with subharmonic resonance is pointed out and examples are given.

A. W. Wundheiler, USA

1551. **Francis D. Murnaghan, "Introduction to applied mathematics,"** John Wiley & Sons, Inc., New York, 1948. Cloth, 6 × 9.25 in., 289 pp., 41 figs., \$5.00.

This book initiates an "Applied Mathematics Series" edited by I. S. Sokolnikoff. It is a graduate text containing the minimum needed by the research physicist and engineer for independent work. Detail is sacrificed to clarity and logic, but this lack is partly compensated by the profusion of exercises which are much more than just practice material. An attractive feature is the excellent display of results (bold type and italics) which enhances the usefulness of the book for reference purposes. Clarity is achieved by means of a frank discussion of the concepts, warnings against misinterpretation and misconstruction, and by indicating jumps in the argument by means of parenthetical "whys." A list of topics by chapter numbers follows.

(1) Vectors and matrices, 42 pp.; (2) Linear vector functions 22 pp.; (3) Function vectors; Fourier series, 27 pp.; (4) Curvilinear co-ordinates, 27 pp.; (5) Laplace's equation, 52 pp.; (6) Spherical harmonics and Bessel functions, 39 pp.; (7) Boundary-value problems, 41 pp.; (8) Integral equations, 59 pp.; (9) The calculus of variations, 30 pp.; (10) The operational calculus, 48 pp.

The contents of each chapter are well rounded. The chapter on vectors does not waste space on the conventional array of involved formulas, but uses it instead to discuss complex vectors and Hermitian space. The vector definition given is that of co-ordinate system type; it is worked out carefully. The chapter on linear-vector functions presents the elements of tensor algebra in matrix symbolics, followed by a presentation of the elementary divisor theory (it is regretable that the differential tensor calculus had to be left out). "Function vectors" are simply functions of one variable regarded as vectors with infinitely many components (elements of a function space); the use of vector language in the discussion of orthogonal developments is a valuable visual aid. The clarity of the concept of variation of chapter 9 (that is, its interpretation as a derivative) deserves special commendation.

A. W. Wundheiler, USA

1552. **A. M. Turing, "Rounding-off errors in matrix processes,"** *Quart. J. Mech. appl. Math.*, Sept. 1948, vol. 1, pp. 287–308.

The main purpose of this paper is to prove that round-off errors in matrix inversion need not accumulate exponentially, contrary to a suggestion of Hotelling. The author's discussion involves omission of "second-order quantities"—in the reviewer's opinion a questionable procedure in round-off error study.

About two thirds of the paper is devoted to brief descriptions of several procedures for solving linear systems of n equations with n unknowns: classical iteration; Gauss's elimination; Jordan's, Morris's, and Choleski's unsymmetrical. An asymptotic ($n \rightarrow \infty$) measure of the work involved is αn^3, $0 < \alpha < 1$, with α different for the different methods.

For the matrix $\mathbf{A} = \{A_{ij}\}$ the author puts $N(\mathbf{A}) = \Sigma A_{ij}^2$ and $M(\mathbf{A}) = \max |A_{ij}|$ and proposes $N(\mathbf{A})N(\mathbf{A}^{-1})/n$ and $nM(\mathbf{A})M(\mathbf{A}^{-1})$ as measures of ill-conditioning.

Turning to the round-off error study, the author proves an exact maximum-error formula $M(\mathbf{B} - \mathbf{A}^{-1}) \leq nM(\mathbf{B})M(1 - \mathbf{AB})/[1 - nM(1 - \mathbf{AB})]$, where $\mathbf{B}$ is the tentative inversion of $\mathbf{A}$. For Jordan's, Gauss's, and Choleski's methods omission of second-order terms leads to a simple formula, cubic in n, expressing the error in terms of two certain basic errors not quite easy to determine.

For the Jordan method a statistical first-order error estimate is given, assuming Gaussian distribution of some basic round-off errors. For the Gauss method exponential error accumulation occurs only with ill-conditioned equations, and only if "we are unlucky." With a few exceptions the author's discussion does not lead to precise statements, and provides rationalization rather than proof. A. W. Wundheiler, USA

Acoustics

1553. M. C. Smith and R. T. Beyer, "Ultrasonic absorption in water in the temperature range 0–80 C," *J. acoust. Soc. Amer.*, Sept. 1948, vol. 20, pp. 608–610.

The experimental attenuation of longitudinal waves in light liquids is greater than that predicted by the classical theories of Stokes and Kirchoff based on the assumption of a single shear coefficient of viscosity. It has been suggested by Debye [*Elektrochemie*, 1939, vol. 45, p. 174] and Frenkel [*Kinetic Theories of Liquids*, Oxford University Press, New York, 1946, p. 208] that this difference is due to a rearrangement of molecules as a result of compression. This process must occur over a potential barrier, and hence requires a finite time. This time lag introduces the equivalent of a compressional viscosity. Hall ["Origin of ultrasonic absorption in water," *Phys. Rev.*, Apr. 1948, vol. 73, p. 775] has recently calculated its value for water.

The purpose of the present paper is to compare Hall's calculations with experiment. The radiation pressure of a wave set up by a quartz crystal was measured as a function of distance, temperature, and frequency. The experimental results, which agree well with those of Fox and Rock [*Phys. Rev.*, 1946, vol. 70, p. 68] and Pinkerton [*Nature Lond.*, 1947, vol. 160, p. 178] obtained by different methods, confirm the calculations of Hall at all temperatures except 0 C where reflection and absorption by ice layers may interfere. The measured attenuation is about three times that calculated from the classical theories. No dispersion is found over the frequency range from 12 to 40 megacycles. Warren P. Mason, USA

1554. M. Strasberg, "Radiation from a diaphragm struck periodically by a light mass," *J. acoust. Soc. Amer.*, Sept. 1948, vol. 20, pp. 683–690.

This paper presents an analysis of acoustic radiation from a clamped circular diaphragm excited by periodic blows at its center from a hammer with mass much smaller than that of the diaphragm itself. The study is based on the assumptions that the duration of impact is short compared with the fundamental period of vibration of the diaphragm and that the motion of the system is periodic with a fundamental frequency equal to the impact frequency.

The nonsinusoidal driving force produced by the hammer is expanded in a Fourier series based on the impact frequency. Three different plausible impact force functions are used. The radiation from the diaphragm is computed by the use of equations previously developed by M. Lax [*J. acoust. Soc. Amer.*, May, 1948, vol. 16] which involve radial modes only and neglect coupling between the modes. The value of the present work would be materially enhanced if there were some error discussion.

In the case of a steel diaphragm vibrating in water the spectrum has intensity maxima in the neighborhood of the resonant frequencies of the various modes of the diaphragm, and extends to a frequency given approximately by twice the reciprocal of the impact time. The energy radiated at its fundamental mode is a maximum if the impact frequency is equal to the fundamental frequency or is a subharmonic of it. However, the efficiency of radiation for a single frequency is not particularly great. Better results may be expected for radiation over a wide frequency band. R. B. Lindsay, USA

1555. D. V. Gogate and P. D. Pathak, "The Landau velocity in liquid helium II," *Proc. phys. Soc. Lond.*, May 1947, vol. 59, pp. 457–461.

The authors have derived by a simpler method Landau's formula [*Phys. Rev.*, 1941, vol. 60, p. 358] for the second velocity of sound, in addition to the normal velocity $(dp/d\rho)^{1/2}$ in liquid helium II. Landau's concept that liquid helium II contains two types of fluids—one ordinary which has nonzero values for entropy and viscosity, and the superfluid for which the above quantities are zero—has been adopted. Equating the flow of entropy and the flow of work appearing in the form of kinetic energy, and using the thermodynamic relation $\partial T/\partial x = (T/C)(\partial S/\partial x)$, the authors obtain the relation for the velocity $u^2 = (\rho_s/\rho_n)(S^2T/C)$, where ρ_n, ρ_s are the densities of the normal and the superfluid, S the entropy, T the absolute temperature, and C specific heat per unit volume. R. N. Ghosh, India

1556. R. V. Baud, "The theory of ultrasonics and their application to materials testing (Über die physikalischen Grundlagen des Ultraschalles und seine Anwendung im Materialprüfungswesen)," *Schweiz. Bauztg.*, 1948, vol. 66, Apr. 3, pp. 185–190; Apr. 17, pp. 215–219.

This paper reviews basic theoretical results relating to the velocity of sound in fluids and solids, to reflection, refraction, and diffraction of sound waves, and to absorption of sound energy. The differences between the behavior of low-frequency and high-frequency waves are stressed.

The paper also outlines the elements of the apparatus used in generating and receiving ultrasonic mechanical vibrations, and describes briefly the methods of locating flaws in materials by means of these vibrations. Experiments are described that showed the presence of oil (instead of air) in the flaws to make detection more difficult. Compressive stress in the region of the flaws was also found to be undesirable. Results of tests on several hundred railroad-car and locomotive axles to determine the reliability of the ultrasonic method of flaw detection are summarized, and it is concluded that the method is promising but must be further developed before reproducible results can consistently be obtained. B. G. Rightmire, USA

1557. L. L. Beranek, "Acoustical properties of homogeneous, isotropic rigid tiles and flexible blankets," *J. acoust. Soc. Amer.*, July 1947, vol. 19, pp. 556–568.

The introduction discusses some of the work reported in the sizable literature on sound absorption in porous materials. The

wave equation is derived, its solutions are given, normal acoustic impedance is discussed, and applications to rigid tiles and flexible blankets are presented. The article contains two excellent charts and eleven figures.

The author's summary states that two waves travel through the material—one primarily airborne and the other primarily structure-borne. From the density of the sample, the volume coefficients of the air and of the skeleton of the material, the porosity, the air flow resistance, the interfiber frictional resistance, and the structure factor, the propagation constants of each of these waves can be calculated. The experimental results indicate that the theory is useful in calculating the performance of the flexible airplane type of blankets over the entire audible frequency range. For rigid tiles, however, the theory appears to fail at frequencies above 1000 cps if the flow resistance is high, and it fails at all frequencies for materials with low flow resistance.

Experiment shows that condensations and rarefactions of the gas in blankets take place isothermally at low frequencies and adiabatically at high. The transfer from one state to the other occurs gradually in the 100 to 2000-cps region. A more complete theory is required to explain the effects of the thermodynamic and viscous losses on the propagation constant of rigid materials.

W. H. Pielemeier, USA

1558. **L. Gutin, "On the sound field of a rotating propeller,"** *Nat. adv. Comm. Aero. tech. Memo.*, no. 1195, Oct. 1948, pp. 1–21 (transl. from *Phys. Z. Sowjet.*, 1936, vol. 9, no. 1).

The periodical forces due to the rotation of a propeller element are expanded into Fourier series. In this process the forward speed of the propeller seems to be neglected. The first harmonics of the periodical forces are introduced into the general equation for the velocity potential produced by a concentrated force. From this potential the sound pressure and the directional characteristics are obtained. The results are in agreement with existing experimental data.

E. Haenni, USA

Ballistics, Detonics (Explosions)

1559. **H. Muraour, "Powders and explosives (Poudres et explosifs),"** Presses Universitaires de France, Paris, 1947. Paper, $4\frac{1}{2} \times 7$ in., 136 pp., 20 figs.

This booklet is a condensation of essential information on gun powders and explosives. It is clear, elementary, and does not discuss theoretical matters. The principal topics treated in its six chapters are: (1) historical matters, (2) different modes of decomposition of explosives, (3) characteristics of explosives, (4) manufacturing of explosives, (5) utilization of powders and explosives, and (6) the question of the existence of superexplosives.

Ahmed D. Kafadar, USA

Soil Mechanics, Seepage

1560. **P. C. Carman and J. C. Arnell, "Surface area measurements of fine powders using modified permeability equations,"** *Canad. J. Res. Sec. A*, May 1948, vol. 26, pp. 128–136.

This is a comparison of previously derived semiempirical expressions for "slip-flow" corrections in the determination of specific area of fine powders by means of gas pressure drop measurements through beds. It is shown that equating of corresponding empirical physical factors in the two best expressions leads to consistent results.

Stanley Corrsin, USA

1561. **H. B. Thornley, "Pile tests for design and construction economy,"** *Civ. Engng. N. Y.*, Sept. 1948, vol. 18, pp. 32–35.

The most dependable test of the bearing capacity of piles is the pile test, in which the soil layers, geometric proportions and forces correspond to reality, unlike load tests on plane foundations. Pile tests have great practical importance since they may give values of load capacity two to three times as large as the pile formulas hitherto used. Thus in the foundation work for the Metropolitan Life Insurance Company's Stuyvesant Town Housing, New York, N. Y., where 35,000 piles had to be driven, the Engineering News formula required piles of 80 to 100-ft length for 30-ton capacity, while pile tests on the job showed that piles of 35-ft length were sufficient.

Pile tests have to be executed during design work, before execution of the construction. The author discusses piles cast in place, instruments necessary for measuring load and sinking-in. The measuring method renders possible the selective determination of point resistance and of mantle friction. Suitable devices even make it possible to carry out pulsating load tests which may be necessary for foundations for machinery producing strong vibrations.

J. Jáky, Hungary

1562. **L. D. Baver, "Soil physics,"** John Wiley & Sons, Inc., New York, 1948, 2nd ed. Cloth, 6×9.2 in., 398 pp., 89 figs., \$4.75.

The author makes a rather extensive survey of work done in soil physics, with complete lists of source material. Most of the book is concerned with tillage problems, but the following sections will be of interest to engineers:

Information from a great number of publications on soil moisture is presented in Chapter VI. The capillary potential and free energy concept of soil moisture are explained and the relationship of soil permeability and soil porosity to the capillary potential curve is used in interpreting the shape of the curve. Also considered is the influence of entrapped air on the movement of moisture in the liquid and vapor phase. There is a brief description of methods employed for measuring soil moisture in situ.

The theory of heat flow in soils and soil factors affecting conduction are dealt with in Chapter VIII. The mechanics of plow action in relation to tillage and the physical properties of soils in relation to runoff and erosion are discussed in Chapters IX and X. New material in this second edition includes a discussion of recent developments in the use of the electron microscope in the study of the crystalline structure of colloidal clays.

Eben Vey, USA

1563. **A. W. Bishop, V. H. Collingridge, T. P. O'Sullivan, "Driving and loading tests on six precast concrete piles in gravel"** (in English), *Géotechnique Lond.*, June 1948, vol. 1, pp. 49–58.

Six reinforced concrete piles of sizes 10, 12, and 14 in. square were driven through soft clay and filling into an underlying gravel stratum. The penetration into the gravel varied from 6 ft to 17 ft. Complete driving records were kept and loading tests were carried out to ultimate failure.

A comparison of the results with two dynamic-pile-driving formulas shows that they do not give consistently good estimates of safe load capacity over the range of pile sizes tested. In the case of the 14-in. piles where the agreement is least satisfactory, both the Hiley and Faber formulas would have led to the driving of more piles than were necessary.

R. L. Bisplinghoff, USA

1564. **J. Jáky, "Stability of earth works in plastic state II. (Sur la stabilité des masses de terre complètement plastiques)"** (in French with summaries in English and Hungarian), *Publ. tech. Univ. Budapest (Müegyetemi Közl.)*, 1948, no. 1, pp. 1–23.

The paper is a continuation of the author's study of the stability

of earth works in the plastic state. Here he deals with the special stress conditions of plastic state.

He first derives a general equation on the basis of which he reviews Prandtl's solution, and rectifies by calculation the evaluation of Jurgenson's squeezing test. He proves that the distribution of vertical stresses under squeezing plates is trapezoidal. A relation is derived between the slenderness ratio and compressive strength of a test specimen. Stress distribution is discussed in the state of triaxial compression, the role of cohesion being evaluated from experimental results.

A chapter deals with shear failure of the subsoil occurring under high dikes and embankments. The critical height of embankments and also the radius of the sliding surface are determined and illustrated by numerical examples. The shape of the theoretical slope is determined. The law of radial stress distribution and a new solution for the stress distribution under strip load are given. Ch. Széchy, Hungary

1565. Robert Quintal, "Seepage networks (Les réseaux d'infiltration)," *Rev. trim. Canad.*, 1947-48, vol. 33, no. 132, pp. 384–396.

If k_x, k_y, k_z are the permeability coefficients in Darcy's law, $u = x(k_z/k_x)^{1/2}$, $v = y(k_z/k_y)^{1/2}$, and h is the hydraulic head $z + p/\gamma$, the Laplace equation becomes $h_{uu} + h_{vv} + h_{zz} = 0$. If the motion is plane, the flow pattern for a nonisotropic soil can be derived from that for an isotropic one. Some applications to seepage under an overflowed dam are considered. Giulio De Marchi, Italy

Geophysics, Meteorology, Oceanography

(See also Revs. 1451, 1490, 1521, 1564)

1566. Y. Miyake and M. Koizumi, "The measurement of the viscosity coefficient of sea water," *J. mar. Res.*, Sept. 1948, vol. 7, pp. 63–66.

An Ostwald viscometer was used, and measurements were made at water temperatures of 0, 5, 10, 15, 20, 25, and 30 C. Solutions of varying chlorinity were obtained for test by diluting sea water having a chlorinity of 19.39 per cent to concentrations of 2, 4, 6, 8, 10, 12, 14, 16, and 18 per cent. The known experimental errors were of the order of 0.2 per cent. The experimental results are presented in a tabular form together with an interpolation formula for temperature effects. H. J. Stewart, USA

1567. G. M. B. Dobson, "Some meterological aspects of atmospheric pollution," *Quart. J. roy. met. Soc.*, Apr. 1948, vol. 74, pp. 133–143.

This paper discusses the effect of wind on the atmospheric pollution produced in large cities by the burning of coal, and gives data on one large English city. Contrary to expectation, it was found that smoke and sulphur dioxide diminish as air drifts downwind over an area still producing pollution. The formation and dispersion of fog are discussed.

The study takes on added significance when the problem of air travel near large cities is considered. W. C. Johnson, Jr., USA

1568. W. H. Munk, "Tracking storms by forerunners of swell," *J. Met.*, Apr. 1947, vol. 4, pp. 45–57.

The forerunners (with periods up to 30 sec) travel faster than the visible swell, and hence give more early information on wind conditions. As a further advantage it is stated that they form a more regular wave system than the mainswell. The forerunners must be recorded instrumentally, and apparatus developed in the United States and Great Britain is described. It is shown that for this purpose the depth of recording instruments could be increased with advantage.

Eleven series of records taken at Pendeen, England, have been examined; each series gives an harmonic analysis, defining the prominent periods, of a twenty-minute record taken every two hours. The formula used in the analysis, $T = 4\pi x/(gt)$, [Lamb, *Hydrodynamics*, Chap. 9], gives the period T of the waves from an isolated disturbance at a distance x from, and at a time t after, the disturbance. The formula is here written $4\pi/(gT) = x^{-1}(t_w - t_s)$, when t_s, t_w are the times of the disturbance and the observation.

From a sequence of the twenty-minute records, a sequence of recorded periods is identified as arising from the same storm disturbance, whence a series of points, giving a linear relation between $1/T$ and t_w (the two constants of the straight line) determine the time and distance of the disturbance. The storm tracks deduced in this way from the wave records are found to be in satisfactory agreement with information from the weather maps. W. R. Dean, England

1569. R. V. Hensley, "Mollier diagrams for air saturated with water vapor at low temperatures," *Nat. adv. Comm. Aero. tech. Note*, no. 1715, Sept. 1948. pp. 1–16 (plus 2 charts).

Two Mollier diagrams are presented which relate the thermodynamic properties of saturated air when the air is in equilibrium with water and with ice at low temperatures. Development of the charts on the basis of the characteristic equation of a perfect gas is described, and their application to various types of problems in thermodynamics and to the solution of a problem involving icing is demonstrated by suitable illustrative examples. John E. Goldberg, USA

1570. J. G. Charney, "The dynamics of long waves in a baroclinic westerly current," *J. Met.*, Oct. 1947, vol. 4, pp. 135–162.

The author summarizes previous papers of C. G. Rossby, J. Holmboe, and H. Solberg based on semiempirical considerations of the gradient wind, and then undertakes to meet the need for an exact mathematical treatment of baroclinic waves. The actual flow is considered to be a small perturbation superimposed on the mean flow. The linearized equations of motion for this perturbation are then derived and the integration is carried through for a baroclinic atmosphere by reduction to a single differential equation of the confluent hypergeometric type. Stability criteria are deduced and it is shown that instability increases with shear, lapse rate, and latitude, and decreases with wave length. Application to the observed averages of zonal winds suggests that the westerlies at our latitude are a seat of constant dynamic instability. The baroclinic wave model exhibits many of the characteristics observed on the weather maps, both with respect to speed of propagation and internal structure. J. Kampé de Fériet, France

1571. P. P. Bijlaard, "On the linear patterns of the earth's crust" (in English), *Proc. kon. Ned. Akad. Wet.*, Apr. 1948, vol. 51, pp. 450–456.

On the basis of an original theory of the initiation of flow lines derived by a combination of the Huber-Hencky-Mises theory of isotropic flow with original concepts concerning the nature of flow lines, an attempt is made to interpret stresses and deformations in the earth's crust in terms of the plastic deformation produced in a thin plate. Formation of island chains and mountain ranges is attributed to plastic buckling of the plate-like crust, the appearance of rifts is attributed to ruptures in the crust which is work-hardened during deformation. A. M. Freudenthal, USA

1572. **S. K. Banerji, "Relationship between wind velocity and temperature in the free atmosphere"** (in English), *Indian J. Phys.*, Apr. 1947, vol. 21, pp. 50–56.

Sir Napier Shaw's formulas giving the relationship between temperature and wind velocity are extended by the author to cover tropical regions where geostrophic conditions are not satisfied. Starting from the rigorous hydrodynamical equations, the author obtains a number of formulas for the computation of upper air temperature from the known distribution of velocities of upper winds as obtained from pilot balloon observations. The formulas giving the closest approximation to actual conditions prevailing in tropical regions are

$$(g/T^2)(\partial T/\partial x) = -2\omega\cos\phi(\partial/\partial x)(u/T) + 2\omega\sin\phi(\partial/\partial z)(v/T)$$

$$(g/T^2)(\partial T/\partial y) = -2\omega\cos\phi(\partial/\partial y)(u/T) - 2\omega\sin\phi(\partial/\partial z)(u/T)$$

where T is the absolute temperature, u and v the horizontal components of wind towards east and north, respectively, ω the angular velocity of the earth's rotation, ϕ the latitude, and g the pressure gradient. The main novelty in the author's modified formulas is that the value of the correlation coefficient $2\omega\cos\phi$ is not assumed to be zero, as was done by Shaw, because such an assumption holds good only in latitudes near the equator (provided u/T remains constant in the entire horizontal field) and not in the tropical regions. S. K. Ghaswala, India

1573. **W. L. Godson, "A new tendency equation and its application to the analysis of surface pressure changes,"** *J. Met.*, Oct. 1948, vol. 5, pp. 227–235.

The author briefly describes the work of Margules, Houghton and Austin, Panofsky, and Raethjen on pressure tendency equations, and then develops his own additional partial differential equations from a consideration of temperature changes in isobaric surfaces. His equation is derived by integrating between isobaric surfaces, while the derivation of the "classical" equation is based on integration between constant-level surfaces.

The author's equation involves a sum of three terms. The first one expresses the effect of warm or cold air advection along isobaric surfaces on the atmospheric density; the second expresses the effect of vertical motion on the surface pressure tendency; while the third gives the effect on the surface pressure tendency of nonadiabatic processes. Applications of the isobaric tendency equation to orographically and thermally induced pressure systems are described, and an illustration given of the magnitude of the terms of the equation at an altitude of 15,000 ft. An analysis for the case of extratropical cyclones suggests that deepening occurs when one or more of the following three conditions are met: (a) Strong warm-air advection in the lower stratosphere, overcompensating the concurrent cold-air advection in the troposphere; (b) a low level of nondivergence permitting subsidence at the level of the tropopause; (c) a potentially unstable and relatively moist warm-air sector. S. K. Ghaswala, India

1574. **V. P. Starr, "On the production of kinetic energy in the atmosphere,"** *J. Met.*, Oct. 1948, vol. 5, pp. 193–196.

It has long been accepted by meteorologists that the kinetic energy of all atmospheric circulations must ultimately come from conversion of part of the incoming solar radiation into energy of motion. It has often been assumed that the rate of kinetic-energy production could be calculated by assuming it equal to the rate of dissipation by friction and turbulence. The present paper demonstrates, among other facts, that the latter assumption is untrue since a portion of the kinetic energy produced is not immediately degraded, but is first transformed. This follows from the major result, obtained by methods of classical hydrodynamics, that the rate of production of kinetic energy of horizontal motion is equal to the product of the pressure and the divergence of the horizontal velocity integrated over the whole space. Regions where this divergence is negative represent sinks of kinetic energy, above and beyond any that may be created by friction.

This paper, therefore, while it really represents a generalization and extension of the ideas concerning energy transformations at the polar front, notably those of Margules ["Über die Energie der Stürme," *Jb. ZentAnst. Met. Geodyn. Wien*, 1905], provides a considerable theoretical advance over previous work, in that it presents a direct method for calculating the rate of kinetic-energy production and transformation, and in that it points conclusively to the surface anticyclones as the kinetic-energy sources, a fact which has only been intuited previously. Its importance should increase as thermodynamic and hydrodynamic processes in the atmosphere are linked up by theory. Joanne Starr Malkus, USA

1575. **Paul Melchior, "Analysis of the motion of the pole on the surface of the earth (Sur l'analyse du mouvement du pôle à la surface de la terre),"** *Bull. Acad. Belg. Cl. Sci.*, 1948, vol. 34, no. 3, pp. 260–273.

This paper aims to give a kinematical description of the observed motion of the terrestrial pole. The author shows that the centroids of the positions assumed during a period of one year, taken at intervals of $^1/_{10}$ year, lie roughly upon an ellipse. Different groups of years, over the period 1920-1939, yield only slightly different ellipses. The author then plots the vectorial differences of the observed positions from the corresponding centroids. These vectors describe a spiral, from the inspection of which the author is led to consider various different periods slightly in excess of one year. He decides in favor of 1.13 years, and finds that with this period the locus of centroids becomes roughly circular. He suggests possible connections of this result with meteorological phenomena. References to twenty-eight papers on the same subject are quoted. C. A. Truesdell, USA

1576. **G. C. McVittie, "The equations governing the motion of a perfect-gas atmosphere,"** *Quart. J. Mech. appl. Math.*, June 1948, vol. 1, pp. 174–195.

In meteorology, the dynamical equations for local motions are generally simplified by regarding the earth as a plane disk and the air as an incompressible fluid. Noticing the very small range of validity of these approximations, the author writes down the equations of continuity, momentum, and energy for an inviscid perfect gas in motion relative to an earth spinning with constant angular velocity, using as co-ordinates: Arc length along a meridian of a reference sphere (the earth) from an arbitrary pole; azimuth angle of this meridian; and normal distance from the sphere.

After simplifying these equations by neglecting certain terms containing a^{-1}, where a is the radius of the earth, the author considers certain types of steady horizontal motions. He concludes that on a small scale, simple horizontal adiabatic rotations (gradient wind) and various combined adiabatic horizontal vortexes and sources or sinks (Rayleigh-Brunt flow) are possible, but that similar large scale motions do not exist. Hence, to describe observed large scale vortical motions, one or the other of the assumptions of adiabatic flow or horizontal flow must be relaxed. C. A. Truesdell, USA

1577. P. Groen, "Note on the theory of nocturnal radiational cooling of the earth's surface, "*J. Met.*, Apr. 1947, vol. 4, pp. 63–66.

A short account is given of a theoretical investigation of the heat loss from the surface of the earth by radiation during nights uniform in air-mass properties and cloudiness. The result may be of interest in connection with ground-frost prediction and with respect to cooling of the earth's surface during a polar night.

The problem solved is that of transient heat conduction in the ground toward the earth's surface, where heat is radiated to the sky at a rate which varies linearly with surface temperature. The temperature is given as a function of the radiation intensity at the initial surface temperature, the thermal properties of the earth, and the rate of increase of radiation intensity with surface temperature. For small values of time the result agrees closely with a previous formula due to D. Brunt [*Quart. J. roy. met. Soc.*, 1932, vol. 58, pp. 389–418] who assumed a constant net rate of surface radiation. No allowance was made by Brunt for the thermal effects of condensation of water vapor or convection transfer to the air. R. L. Pigford, USA

1578. Jeou-Jang Jaw, "Theory of unstationary wind current" (in English), *Sci. Rep. Nat. Tsing Hua Univ. Ser. A*, Oct. 1947, vol. 4, pp. 363–378.

A horizontal and uniform wind of variable direction and magnitude blows upon the plane surface of an incompressible fluid (the ocean). The motion of the fluid is assumed to be plane and uniform also. The rotation of the earth is taken into account.

The case of steady flow has been treated by V. W. Ekman who found that the constant and uniform fluid velocity makes a 45-deg angle with the wind direction. The transient case has been treated by J. E. Fjeldstad who reduced it to an integral equation [*Z. angew. Math. Mech.*, 1930, vol. 10].

In the present paper the author solves the transient flow problem by means of operational methods, and computes it numerically in three special cases. In the first case the flow direction remains constant, but the speed varies sinusoidally. This result is essentially different from that of Ekman because the flow does not asymptotically approach his solution but oscillates about it indefinitely. For standard conditions the total angle of oscillation is 18°46′. Ratip Berker, Turkey

Lubrication; Bearings; Wear

(See also Revs. 1447, 1493)

1579. W. Weber, "Viscosity measurements of fluids under high pressures. Part 2 (**Messung der zähigkeit von Flüssigkeiten bei höheren Drücken**), **"***Angew. Chem. B*, Apr. 1948, vol. 20, pp. 89–96.

This paper describes two series of experiments, conducted on 20 different oils, in order to investigate the relation between viscosity and pressure at various temperatures. The viscosity measurement was made using a small sphere falling along an inclined tube. A first series covered pressures up to 1000 atm and temperatures up to 60 deg; a second series on which fuller details are given, covered pressures up to 200 atm only, but temperatures up to 120 deg.

The analysis of the results is very careful. For each oil the pressure coefficient of the logarithmic relation between viscosity and pressure was determined; this relation has been confirmed. The dependence of the pressure coefficient on the temperature has been studied but none of the pertinent empirical relations proposed by previous authors has been satisfactorily confirmed. Some efforts are made to connect the physical characteristics involved with the chemical nature of the oils.

Duilio Citrini, Italy

Marine Engineering Problems

(See Revs. 1470, 1541)